AGRICULTURAL ENGINEERING

JANUARY • 1952

Results of Brooding Poultry with Infrared Energy — *Vernon H. Baker and James H. Bywaters*

The Application of Universal Joints to Farm Machinery — *Fred M. Potgieter*

Mathematical Analysis of the Offset Slider-Crank Mechanism — *Andrew J. Asher*

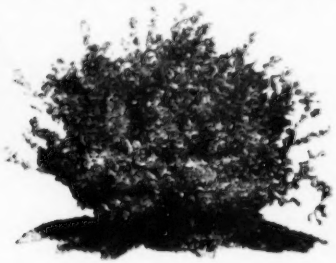
Evaluation of Air Resistance to Falling Drops of Water — *Robert L. Green*

A Basic Concept of Equilibrium Moisture Content — *S. Milton Henderson*

THE JOURNAL OF THE AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS

NEW CASE MOVIE SHOWS HOW TO SAVE FEED VALUE

Nature Puts it IN



How To Keep it There?

Hay can hold no more nourishment than did the plants of which it was made. Hay as commonly put up loses a tragic proportion of its feed value, particularly of its precious proteins and vitamins. Teaching farmers and students how to save the maximum of hay's healthfulness is to promote a more prosperous agriculture, a healthier populace.

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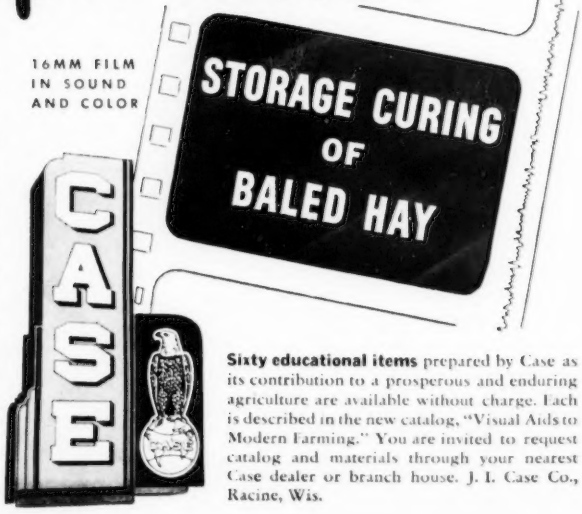
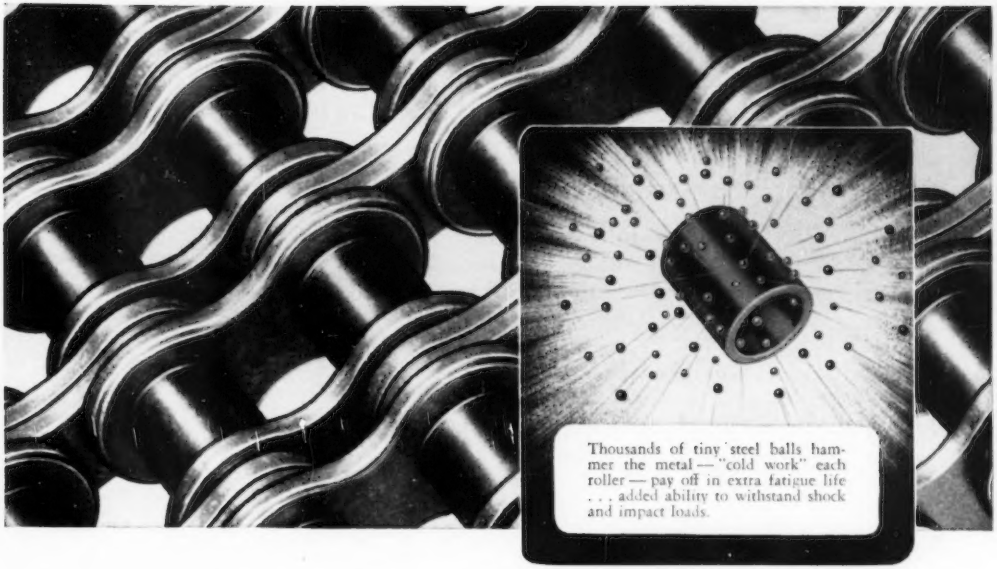


Sixty educational items prepared by Case as its contribution to a prosperous and enduring agriculture are available without charge. Each is described in the new catalog, "Visual Aids to Modern Farming." You are invited to request catalog and materials through your nearest Case dealer or branch house. J. I. Case Co., Racine, Wis.



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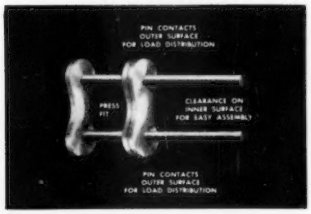
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PRESS FIT
CLEARANCE ON INNER SURFACE FOR EASY ASSEMBLY
PIN CONTACTS OUTER SURFACE FOR LOAD DISTRIBUTION

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AGRICULTURAL ENGINEERING

Established 1920

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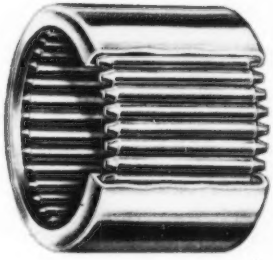

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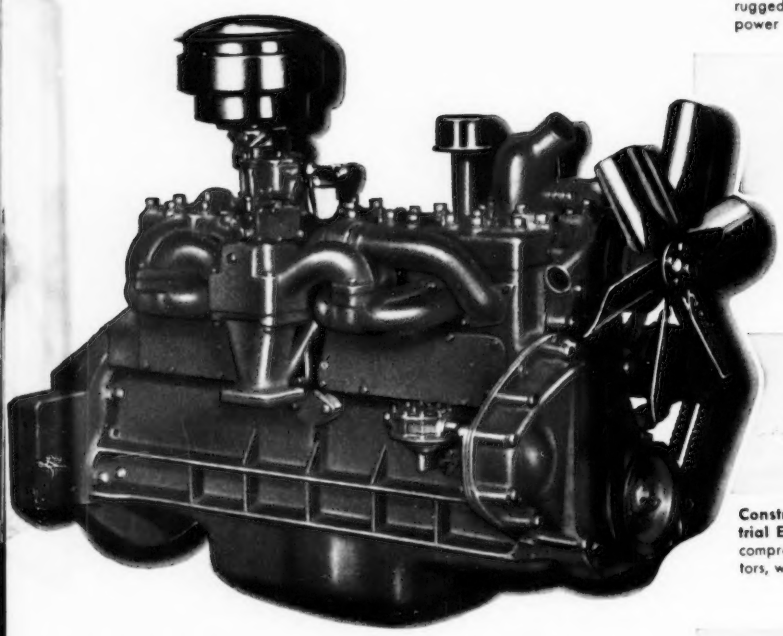

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HORSEPOWER WITH A PEDIGREE

Windows in this remodeled Wisconsin barn bring in the winter sun for extra heat. Note that these windows are large panes, free from light-robbing and dirt-catching cross-members.

This barn was remodeled for BETTER PRODUCTION

IT'S WARMER in winter because big windows flood the interior with heat-saving, health-building sunshine. A tremendous amount of sun heat can enter a building through windows facing south to catch the slanting rays of the winter sun. A roof overhang or tree plantings can be used to shade these windows from the high summer sun.

IT'S *KEPT* WARMER because it is an insulated barn. The windows are *Thermopane** insulating glass—two panes with dry air hermetically sealed between them. Less heat escapes through the glass—only half as much as with windows of single glass.

IT'S DRIER due to the combination of extra warmth and a ventilation system. Warmer air can hold more moisture—hence the ventilators are better able to carry moisture out of the building. That not only provides a more healthful condition for livestock, but also protects the structure. *Thermopane* reduces condensation on the windows—moisture which single glass takes out of the air and leaves *inside* the building.

Warmer—drier—these are conditions which livestock and poultry respond to with better health and more production of milk, meat and eggs. And, of course, the building is mo. comfortable to work in.

Thermopane is left in all year (when shaded it actually helps keep buildings cooler in summer). It is easily installed—in fixed sash or windows that open. *Thermopane* is sold by glass and building supply distributors and dealers. Write for our book on "Improved Farm Building Daylighting."

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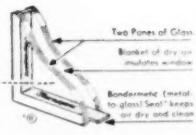
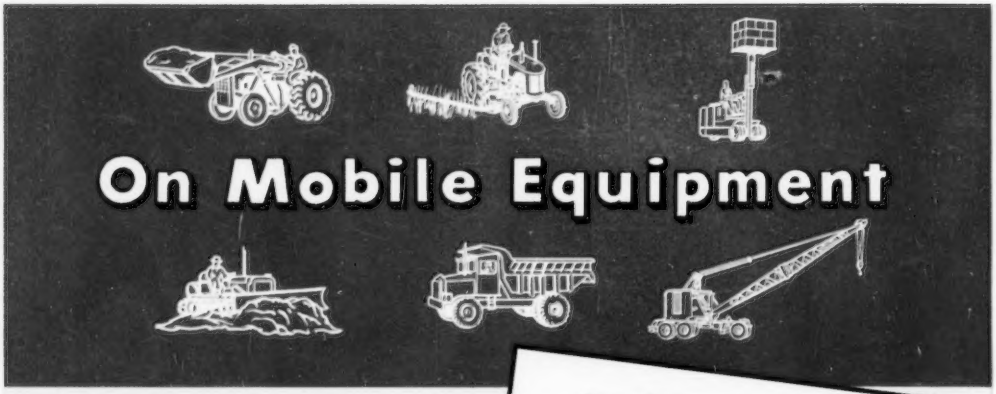
LOF GLASS *Thermopane*

LOOK FOR THE NAME ON THE SEAL BETWEEN THE PANES





On Mobile Equipment

These Vickers Balanced Vane Type Pumps are especially designed and built for the severe service encountered with mobile equipment.

Their design automatically compensates for wear throughout pump life. Correct clearances are maintained continuously so that efficiency and delivery rate remain high. As a result, it is not necessary to select a larger pump to allow for loss of delivery under normal service conditions.

Hydraulic Balance . . . an exclusive feature of Vickers Vane Type Pumps for many years . . . eliminates pressure-induced bearing loads, providing longer life and less maintenance.

These Vickers Pumps are available in three basic sizes (shown at right) with a total of ten nominal delivery ratings and a variety of mountings. By unbolting and rotating the pump head the outlet may be placed parallel, opposite, or at right angle in either direction to the inlet. This greater adaptability to individual requirements means easy and inexpensive installation.

For additional information about these pumps (also double pumps) write for new Catalog M-5100. There is a Vickers Application Engineer near you who will be glad to discuss your hydraulic pump problems.

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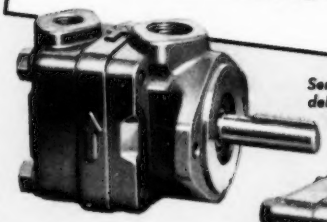
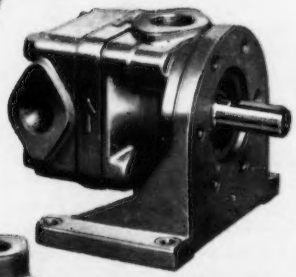
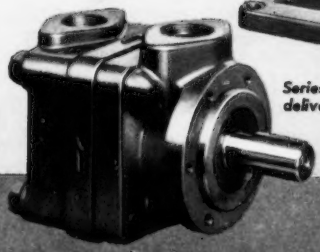
Do a Better Job and Last Longer...
AT LOWER OVERALL COST



Series V-200 pump made in 4 delivery ratings—2 to 11 gpm.



Series V-300 pump made in 4 delivery ratings—12 to 24 gpm.



Series V-400 pump made in 2 delivery ratings—28 and 36 gpm.

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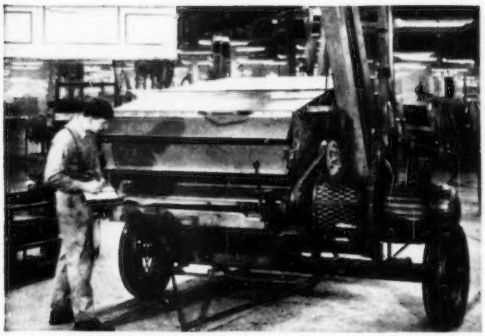
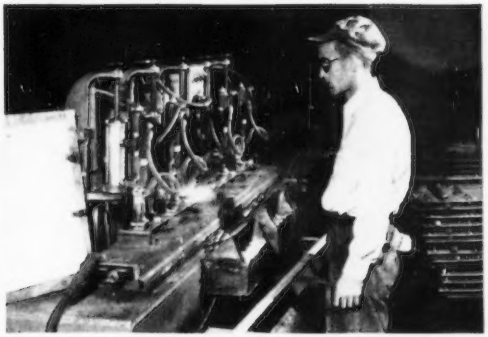
How the McCormick No. 64 Harvester-Thresher earns its IH trade mark



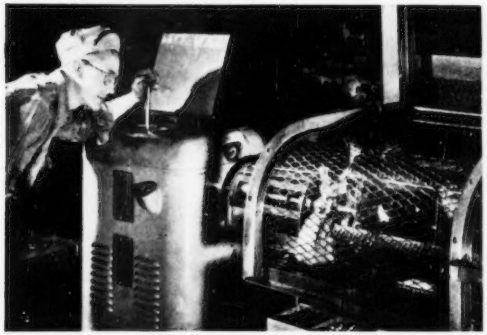
The No. 64 Comes Off the Line "Threshing"

Here is an inspector checking the "biggest of the 6-footers" at 1200 rpm. cylinder speed. He goes over *every* moving part . . . makes sure all settings and adjustments meet high IH standards. This is one of over 5,000 different inspections that safeguard the quality of McCormick harvester-threshers.



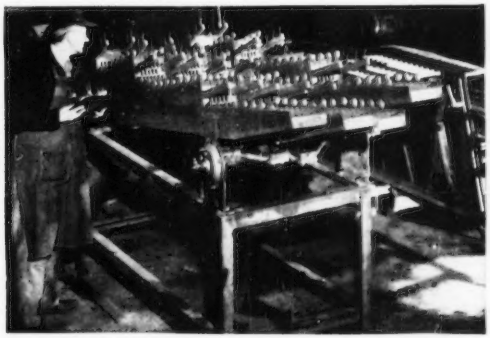
Robot Welder Makes Hole-Free Rasp Bars

Supporting studs are made part of cylinder rasp bars by this automatic welding machine. There are no bolt holes to weaken the bars or to break their continuous, ribbed threshing surfaces. This means cleaner, more complete threshing at the cylinder. Quality control guards against defective welds.



Cylinder Balance Can't Vary an Ounce

Every cylinder is statically and dynamically balanced for smooth, vibration-free operation. It is run at 1050 rpm. in this dynamic balancer and balanced within limits of one-half ounce. Good balance prolongs bearing life, and permits setting cylinder and concave close together for threshing clover and other small seed.



Destruction Tests Head Off Field Failures

Here is a combine straw rack operating at normal speed under heavy overload. The straw rack illustrated has been run for 378 hours of operation without adjustment or repair. This test will continue until the straw rack fails. IH engineers use destruction tests, which localize and measure wear, to contantly improve McCormick farm equipment.

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International Harvester products pay for themselves in use—McCormick Farm Equipment and Farmall Tractors . . . Motor Trucks . . . Crawler Tractors and Power Units . . . Refrigerators and Freezers—General Office, Chicago 1, Ill.

This Iowa Farmer Says:
"WHERE OTHER TIRES HANG UP Firestone CHAMPIONS GO RIGHT ON THROUGH"

"I farm 210 acres of black loam, and for the kind of soil conditions I have, I like these Firestone Champions best. When the ground is hard, they bite in and take a good hold — and when it's soft, they take me through where other tires hang up."
W. E. WEDEMEYER, DONAHUE, IOWA.

MORE AND MORE farmers are switching to Firestone Champion Open Center Tires — and glad of it! They find that the bars take a sharper bite because they're tapered, take a stronger hold because they're curved. And, because the tread of this tire is wider and flatter, it has more bar rubber to grip the soil for extra traction, more bar rubber to stand up on the road for extra traction life.

Try a set of Firestone Champion Open Centers on your tractor. Or, if you prefer Firestone Champion Traction Center Tires for your soil conditions, you can get them, too. Only Firestone offers you a choice between the most advanced Open Center and the one and only Traction Center Tire on the market today.

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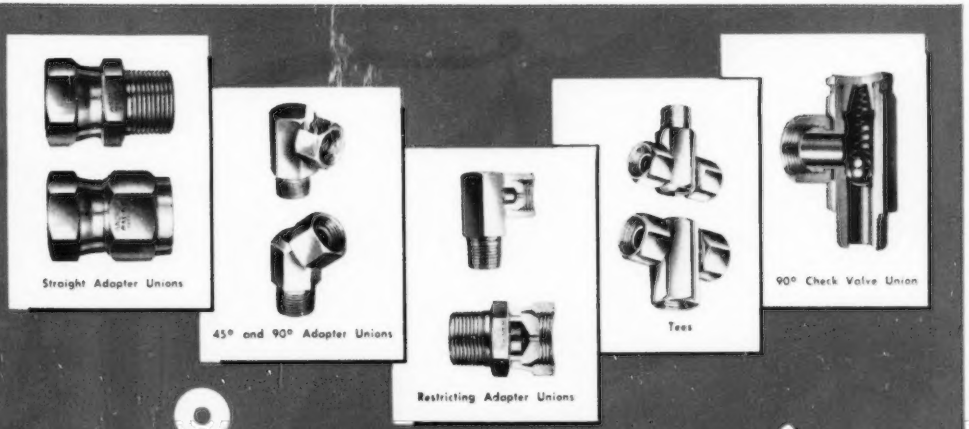

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Save You Assembly Time and Money

Anchor Ductile Sleeve Couplings assembled on two wire braid hose for high pressures.

Anchor Sleeveless Couplings assembled on either single wire braid hose or two rayon braid hose for medium or low pressures.

Anchor Clamp-type Couplings are ideal for field service use and emergency repairs. Easy to put on and take off—withstand high pressures.

Use Anchor Assembled Hose Units with the outstanding fittings shown above. You'll have less trouble in the shop on assembly — and less trouble in the field on the job.

ANCHOR COUPLING CO. INC.
Factory: Libertyville, Illinois • Branch: Detroit, Michigan

Time is money And whenever you save time, you reduce costs.

That's why it pays to use Anchor Adapter Unions and Related Fittings. You see, they're designed especially to speed the attachment of Anchor hydraulic hose assemblies to equipment of all kinds.

In addition to cutting assembly costs, Anchor Adapter Unions and Fittings have these important advantages:

- They provide a leakproof ground-joint connection.
- They are small in size, require little space, and provide a neat appearance.
- You can connect and disconnect them many times without destroying the seal.
- Made from solid steel bar stock and plated to prevent rust, they stand up under the toughest service conditions.
- Their use lets you eliminate one or more pipe-thread joints—gives you a better piping job.
- Assembly in confined spaces is quicker and easier.

The Anchor line of Adapter Unions and Related Fittings is the most complete line available. Save yourself time and money—select those that fill your specific needs.

Send for complete information on Anchor Adapter Unions and Fittings

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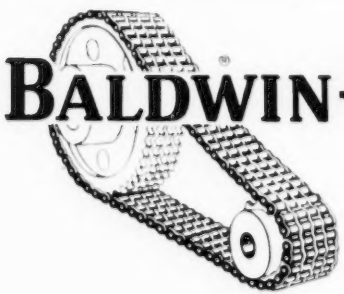
Double Savings With Double

When you specify Baldwin-Rex® Double Pitch Roller Chain for either drives or conveyors, you save two ways . . . you materially cut costs and reduce weight. Why? . . .

. . . Because with Baldwin-Rex Double Pitch you get all the precision craftsmanship, durability and strength of standard roller chains—*but* at lower cost. You get the identical highly finished round parts . . . pins, bushings and rollers . . . of roller chain. You get the same long-wearing qualities and ultimate strengths.

The pitch, or distance between pin centers, of double pitch chain is twice the pitch of standard roller chain of the same width and strength. Thus, for each pitch of chain, you save one set of round parts. You get a high quality chain that *costs* less . . . that *saves* weight!

Double pitch roller chains are NOT a substitute for standard roller chains. They have a very definite field of application in power transmission. Where speeds are



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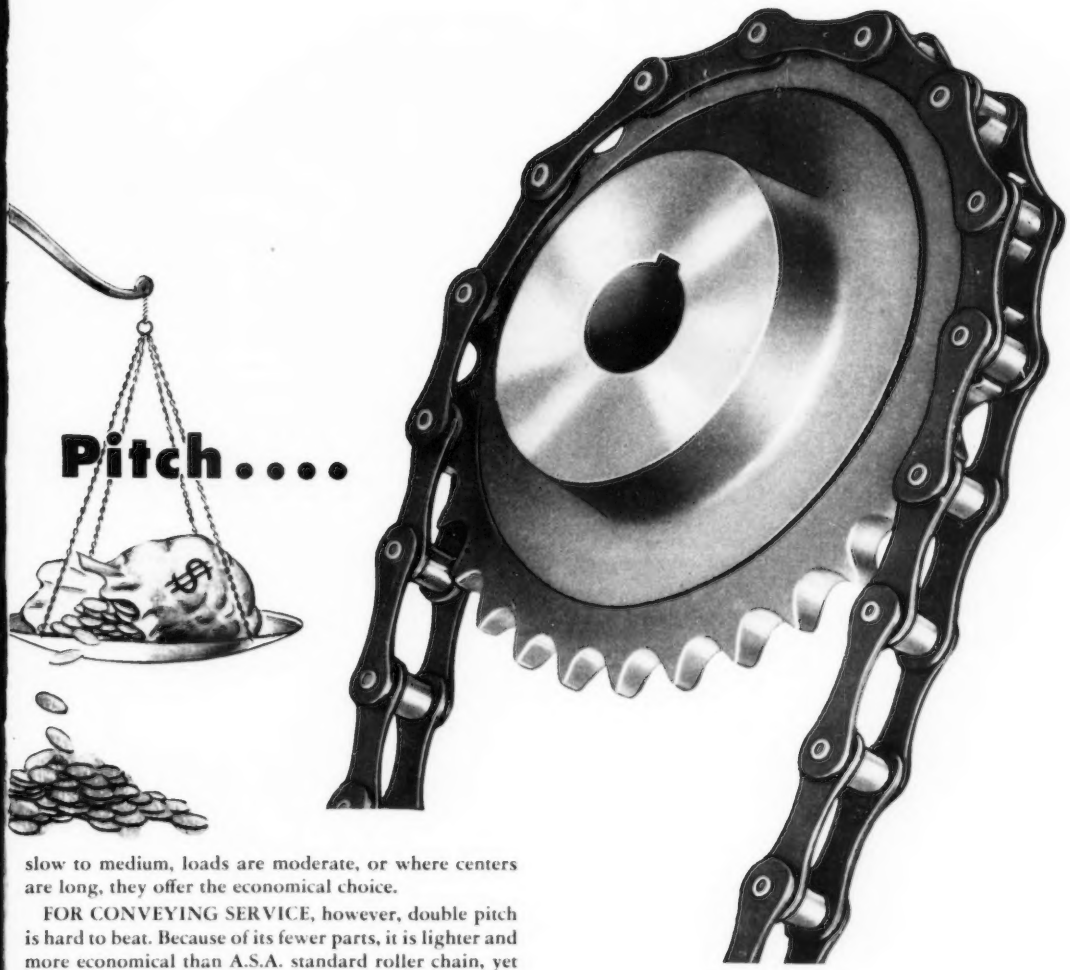

slow to medium, loads are moderate, or where centers are long, they offer the economical choice.

FOR CONVEYING SERVICE, however, double pitch is hard to beat. Because of its fewer parts, it is lighter and more economical than A.S.A. standard roller chain, yet it retains all the precision workmanship of standard roller chain. The conveying series assures extra long life because the straight-edged plates provide greater wearing surface. A wide range of standard attachment links is available for double pitch chains.

Our new booklet No. 51-2 contains all the facts, including dimensions, specifications, prices and horsepower tables. Just call your nearest Baldwin-Rex Field Sales Engineer or mail the coupon.

52-421

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EDITORIAL

Agricultural Engineering in 1952

WHAT meaning can agricultural engineers add to the year 1952? What values can be created? What service rendered? What special obligations may be encountered? What opportunities may justify special effort along certain lines? A surmise or two, based on present indications, may be in order. The confused situation of the world and the confused outlook of many people seem to justify more than ever some attempt to look ahead.

RECOGNITION

To the extent that agricultural engineering has gained recognition as a distinct branch of the whole engineering profession, it has undertaken definite obligations and responsibilities. It must share and help to deal with the problems and prospects of the engineering profession. One rare opportunity for agricultural engineers to join with others in a profession-wide activity is already under development. The ASAE has received and accepted an invitation to participate in the Centennial of Engineering.

CENTENNIAL OF ENGINEERING

A national Centennial of Engineering has been scheduled to be held in Chicago during 1952. Its purpose is to improve the public relations of the engineering profession.

Toward the realization of this purpose agricultural engineers can contribute established contacts and a basis for interpreting engineering to one major element of our population—farmers, and the industries, sciences, and other groups serving agriculture.

Incidentally, this centennial will provide an especially favorable atmosphere for interpreting our field to additional representatives of other branches of engineering, and to whoever else may be concerned. In fact, it sets the stage for a year of special emphasis on reorienting and clarifying viewpoints on our particular field of service.

RECRUITING STUDENT ENGINEERS

During 1952 a great deal will undoubtedly be done to interest high school seniors in preparing for careers in engineering and in the other sciences and professions.

In this competition for brain power, there may be some temptation to paint too rosy a picture of engineering.

It is important that more young men be interested in careers in engineering. It is important that every young man who wishes to try to make the grade in engineering training have the opportunity to make that try. It is also important that high standards in engineering training be maintained. There is no easy road to the discipline of character and intellect; the development of manual skills and ability to work with others, which combine to distinguish an engineer.

The best way to attract prospective engineers may be to present engineering as a challenge; a life of measuring up to high demands; a man's work from the first day of freshman classes.

Drawing its recruits mostly from farm boys who have learned early the meaning and satisfactions of a man's work, agricultural engineering should readily attract its share of the potential engineering material graduating from our high schools.

ENGINEERING IN NATIONAL DEFENSE

Science and all branches of engineering face, in 1952, a task of dispelling a popular illusion in regard to national defense.

Many well-meaning people are slightly mixed up as to the application of our ideals of equality and patriotic duty to our present defense problems.

Defense against modern methods and equipment used by predator nations in attacking their neighbors requires a new interpretation of patriotic duty and sacrifice.

There is no equality of hazard in the front lines of defense; no refuge from danger in civilian status or distance from our borders. Sacrifice is no measure of the effectiveness of our defense, or the value of individual contributions to defense.

Our defense requires, not more men with equal status as cannon fodder, but more effective organization and utilization of our manpower and other resources, so that the smallest possible number of our people may be called upon to give their lives in the defense of our freedoms and ideals.

That means continued training of young men to fill the ranks of science and engineering, one of our strongest defense armies. It means using scientists and engineers as such, in the types of armed and civilian defense work where they are individually qualified to serve most effectively.

PRESSURE FOR PROGRESS

One could scarcely attend the ASAE Winter Meeting at Chicago in December without sensing more strongly than ever a definite pressure for progress in agricultural engineering.

A contributing factor is undoubtedly the scarcity and high cost of farm labor. This is usually attributed to the competition of urban industries and expansion of our armed forces. It may also be due in part to a growing cultural insistance that human effort count for larger material results. Engineering is implementing more than farms and factories. It is implementing our expanding concepts of the value of the individual human life.

Another source of pressure is our growing sense of obligation to aid in the technological development of other countries. Some are already progressing rapidly. Others are rich in resources and the urge to progress, but scarcely know where and how to make a start in developing their resources. In many cases an important part of their problem is low productivity per man hour on their farms, due to many factors, including scarce and primitive farm equipment. Agricultural engineering will be basic to any integrated, well-balanced adjustments they may make toward higher levels of living.

Defense production goals for agriculture, to be met with reduced labor and a reduced supply of new farm machines, will be as high as in 1951, or higher. The alert, fairly prosperous, and patriotic body of commercial farmers who will do their best to meet these goals will look to agricultural engineers for methods and equipment help on the physical problems of boosting and handling biologic production.

Long-range prospects for competition in a future farm buyers market call for agricultural engineering research and development now. It is the quality-value approach to satisfied customers with sustained buying power.

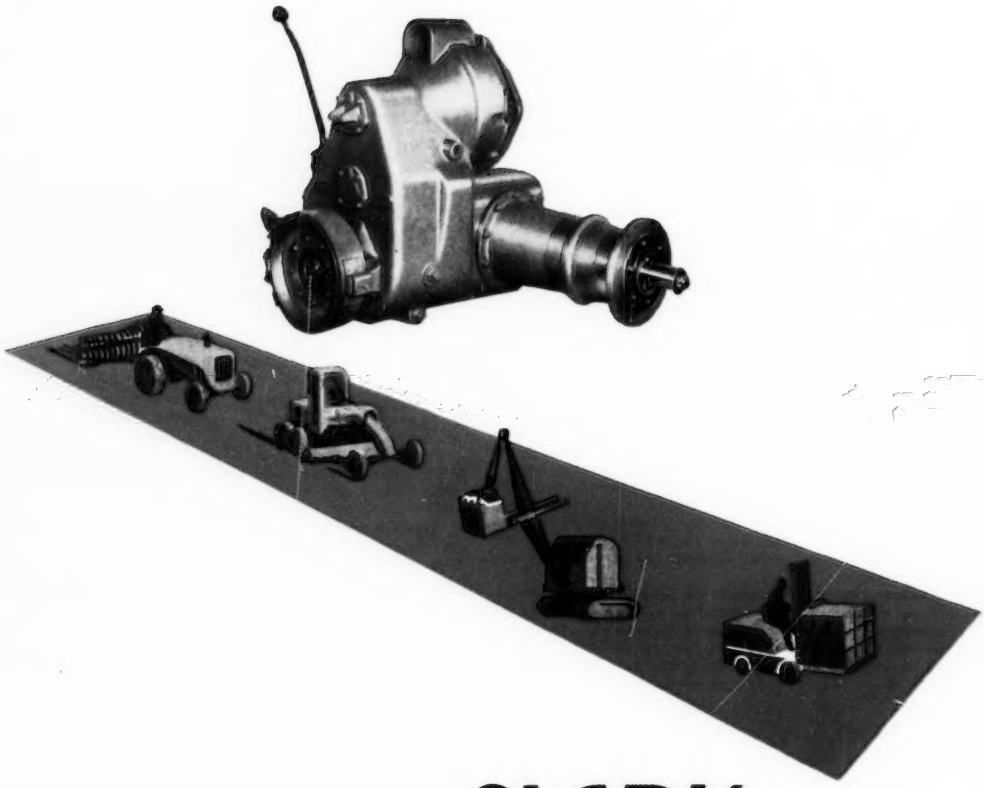
UNFINISHED BUSINESS

Strong handles on farm equipment, hand tools, the volume of strong-arm work remaining on some farms; farm losses from fire, accidents, pests, weather; losses of soil, fertility, organic matter, and other productive capacity; field and storage losses of crops and livestock products—all these and more are signs of unfinished business for agricultural engineers.

These are times of unusually high material demands for defense and for better living for a large part of the world's population. There is a swelling tide of belief that better living is a physical and economic possibility, and a right to be realized. It emphasizes the importance of increased production, conservation of human life, energy, natural resources, and products. It puts a premium on increased efficiency in production, government, private enterprise, and especially in utilizing the physical laws, energy, and materials of nature, the province of the engineer.

MAKING GOOD IN ENGINEERING

The year 1952 will likely bring continued high demand and competition for the services of engineers of all kinds. This demand is based on high expectations. It will continue only to the extent that engineering performance measures up to those expectations.



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AGRICULTURAL ENGINEERING

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Brooding Poultry with Infrared Energy — Part II

By Vernon H. Baker and James H. Bywaters

ASSOCIATE MEMBER ASAE

A PAPER, Part I of this series (1)*, and other reports (2, 3) presented a summary of the infrared brooding work for 1949-50, that was conducted by investigators assigned to the cooperative poultry brooding project of the Virginia Agricultural Experiment Station and the Division of Farm Electrification, U.S. Department of Agriculture. The information contained herein is a progress report of the work for 1951. Other investigators (4, 5) have released reports on infrared brooding of chicks for the 1951 season.

These brooding studies were continued to investigate other aspects of brooding poultry with infrared energy. It is recommended that the previous paper (1) be reviewed prior to studying the contents of this one. The previous paper discusses the types of infrared lamps available and their energy-distribution patterns, energy and temperature requirements for three breeds of chickens, the projected area and surface area of a chicken, litter conditions, physical observations of chicks, wiring, and power outages.

This paper was presented at the annual meeting of the American Society of Agricultural Engineers at Houston, Tex., June, 1951, as a contribution of the Rural Electric Division.

The authors: VERNON H. BAKER and JAMES H. BYWATERS, respectively, associate agricultural engineer and research poultryman, Virginia Agricultural Experiment Station, Blacksburg. Mr. Baker is also collaborator, Division of Farm Electrification (BPISAE), U.S. Department of Agriculture.

AUTHOR'S NOTE: The authors acknowledge the contributions of Dr. Clayton E. Holmes, associate poultryman, and McNeil Marshall, associate agricultural engineer of the Virginia Station, and the assistance of B. M. Cannon, J. N. Jones, and M. W. Toupo, graduate students, and T. W. Waldrop, senior agricultural engineering dept., Virginia Polytechnic Institute.

*Numbers in parentheses refer to the appended references.

Summarizing briefly the previous work, chicks were brooded for two years with infrared lamps. The electrical energy consumption for this method of brooding during the winter months was 2 to 3 kw-hr per chick as compared with about 0.5 kw-hr per chick for conventional electric brooding. The litter remained dry throughout the brooding period in the quonset brooding house and was not changed. There was no danger of fire as a result of litter igniting from the radiated energy if the infrared lamps were placed 12 in. or more above sawdust, ground corncobs and straw. The use of clean, fine sand under the heated area proved to be a satisfactory type of litter. There was no significant difference in weight gains or in feathering for chicks brooded with infrared lamps when compared with chicks brooded with other systems. Pullets from the infrared-brooded flock began to lay 2 to 3 weeks before their 1, 2 and 3-weeks older sisters brooded with other systems. The chicks brooded with infrared lamps had light 24 hr each day for the first 8 weeks, while their sisters brooded with other systems had no light at night. This may have caused the earlier maturity in the infrared brooded flock. However, after the first eight weeks, neither group had artificial light at night. The mortality rate for the 1949-50 work was as low or lower than for other methods of brooding.

EQUIPMENT AND PROCEDURE

The infrared brooding research in 1949-50 was conducted in a 20 x 40-ft quonset building. Two new colony-type brooder houses, each 10 x 12 ft in size, were constructed for the 1951 studies. One of these houses is insulated and mechanically ventilated and the other is uninsulated, with natural ventilation. Two hundred chicks were brooded in each of these houses and approximately 1170 chicks were brooded in the quonset building. The electric energy consumption of the lamps, on and off operation of the fan, moisture content of the litter, mortality, feathering, rate of weight gained and breast angle were observed and recorded. Temperature and relative humidity were recorded in each colony house with hygrothermographs. These instruments were calibrated weekly with an aspirating psychrometer. Five different arrangements of the infrared lamps were constructed: a one-lamp brooding unit with and without hover, a three-lamp unit with horizontal and tapered hover or baffle, and a six-lamp unit without hover.

Two New Colony Houses. The main objective in building two additional houses was to provide space for conducting experiments on brooding small replacement flocks with infrared lamps. It was decided to conduct preliminary investigations on ventilation and insulation problems along with the brooding. Two hundred day-old New Hampshire in-crossed chicks were placed under the infrared lamp arrangement in each colony house as shown in Fig. 1. This arrangement consists of three 250-w

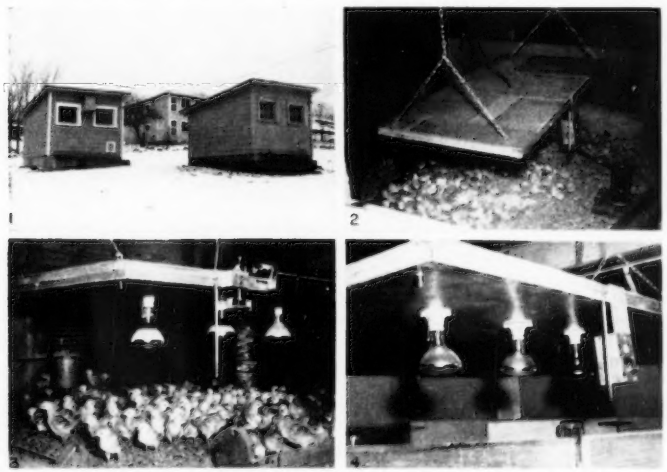

Fig. (1) Mechanically ventilated and insulated house to left; natural-ventilated and uninsulated house to right. (2) Looking down on baffle that supports three infrared lamps. (3) Chicks under lamps in uninsulated house. (4) View of three lamps, porcelain receptacles, and thermostat.

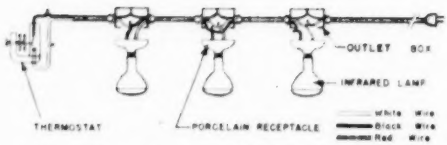

Fig. 2 Wiring diagram for horizontal-baffle brooder using 2-conductor and 3-conductor No. 12 non-metallic cable

infrared lamps placed approximately 16 in apart, mounted vertically under the center of a 30 x 60-in baffle supported from the ceiling with chains. The main reason for mounting lamps under the baffle was to change the location of convection currents and reduce drafts. The bottoms of the lamps were 15 in above the litter for the first four weeks. Then, after most of the chicks were feathered, the lamps were raised to 20 in above the litter. The inside area of each of the two houses was about 110 sq ft. This allowed 0.55 sq-ft floor area per chick. The two end lamps were controlled by a wafer-type thermostat. The thermostats were set according to the chicks comfort. A thermometer was used as a guide for setting the thermostat; however, the best way was to set the thermostat according to needs of chicks and forget about thermometer reading. Chicks that were under an adequate amount of infrared were calm and spread out evenly. There was no supplemental heat in the two colony houses. The center lamp was manually controlled. A 12-in guard board was placed around the heated area for the first week to confine the chicks to that zone. The chicks in the two small houses were weighed at the end of 4, 8 and 12 weeks. At the end of 8 weeks the pullets from each house were moved to range houses to be observed further. The cockerels were left in the original houses.

Sufficient ventilation was apparently supplied by infiltration until the chicks were 3 weeks of age, after which time it was necessary to start the fan in the insulated house and tilt the front windows in the uninsulated house.

Mechanically Ventilated and Insulated House. The insulated brooder house is shown in the left half of Fig. 1 (1). It was built on 6 x 8-in runners to make it movable. Floor joists were 2 x 8 in laid crossways on the runners. One-inch boards were nailed to the under side of the joists and the spaces between the joists were filled with sawdust. A subfloor was installed on the joists and one layer of moisture-proof building paper was put down between the subfloor and the finish floor which was No. 2 pine. The walls were frame constructed, weather-boarded on the outside over one layer of moistureproof building paper, and finished on the inside with 25/32-in rigid insulation board. The insulation board adjacent to the floor was protected from destruction by the pecking of the chicks by installing ¼-in plywood paneling 30 in high around the walls. The rafters were 2 x 4 in with solid 1-in board sheathing. Corrugated galvanized-metal roofing was installed over one layer of moistureproof building paper. Rigid insulation board, like that used on the inside walls, was installed on the underside of the rafters to form the ceiling. The calculated U values for the walls, windows and ceiling was 0.207, 1.1, 0.189, respectively. The U value for the floor was 0.052. The $A \times U$at for walls, windows and ceiling was calculated to be 89 Btu per hr per deg F and the $A \times U$ value for the floor was 6.24 Btu per hr per deg F. The total heat transferred using $\Delta T = 40$ for walls, windows, ceiling and $\Delta T = 30$ for floor, was 3747 Btu per hr.

The insulated house was equipped with a 12-in ventilating fan, thermostatically controlled, that delivers approximately 900 cfm at free air delivery. Air enters this house at the back through inlets between the rafters. The fan exhausts the air from near the floor through an inside duct between the windows. The fan was turned on after the first three weeks of brooding.

Natural-Ventilated House, Floor and Walls Uninsulated. This brooder house is shown in the right hand section of Fig. 1 (1). The construction is identical to the completely insulated house except that the subfloor on the underside of

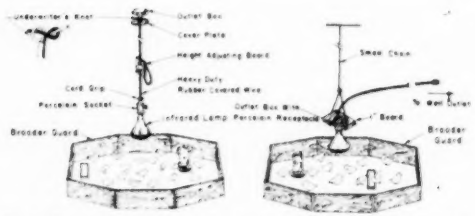

Fig. 3 Two methods of suspending individual lamps. Length of rubber-covered wire and chain should be such that minimum distance between bottom of lamp and litter is 12 in

the floor joists and the sawdust in the spaces between the joists were omitted. The inside walls of this house were not finished with insulation boarding, but the ceiling was finished the same as in the insulated brooder house. There are two windows in the front (south side) of each of these houses. In this house ventilation was accomplished by natural circulation, the windows tilting in at the top, and air inlets, or outlets as the case may be, were located under the back eave in between the rafters. The calculated U value for walls, windows, ceiling and floor was 1.56, 1.1, 0.189 and 0.293, respectively. Using the same conditions and formula as described above, the heat transferred through walls, ceiling, floor, and windows was 8975 Btu per hr.

Quonset Building. The insulated 20 x 40-ft quonset building was used to brood a group of inbred White Leghorns, White Rocks, New Hampshire crossbred chicks at the Virginia Agricultural Experiment Station (1). This house was divided into four pens with each pen having two 375-w, heat-resistant-glass-type infrared lamps equipped with aluminum hovers (Fig. 5). There were approximately 146 chicks under each lamp, making a total of approximately 1170 chicks brooded in the quonset building. The inside dimensions of the quonset building are about 19 x 39 ft. Fewer chicks were placed under the lamps than in previous years in order to prevent crowding. Sawdust was used as litter.

The eight 375-w (hard glass) infrared lamps in the quonset building were connected, after the third week, to a Minneapolis-Honeywell mercury-type air thermostat mounted in the center of the quonset building 4 ft above the floor. Six of the lamps were equipped with hovers (Fig. 4). Two lamps did not have hovers as shown in Fig. 3. The thermostat was set at 75 F for the third, fourth and fifth week and was reduced to 65 F for the remainder of the brooding period. The thermostat controlled a magnetic switch which in turn controlled the infrared lamps. Incandescent lamps provided light through

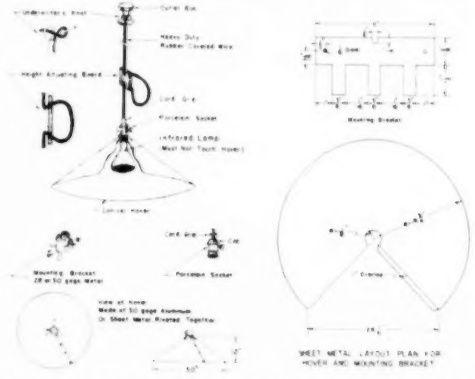

Fig. 4 Single lamp hover with mounting bracket. Length of heavy-duty, rubber-covered wire should be such that minimum distance between bottom of lamp and litter is 12 in

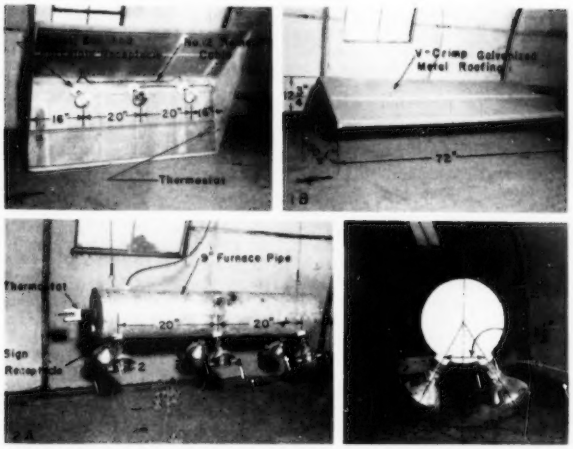

FIG. 5 (1A, 1B) Views of three-lamp, hover-type brooder. (2A, 3B) Six-lamp unit with lamps 2, 3 and 6 controlled by thermostat. Each row of lamps placed 40 deg apart.

the brooding period when the infrared lamps were off. A thermostatically controlled ventilating fan was installed in the east end of the quonset building. This fan is rated at 1650 cfm at free air delivery. One 1000-w radiant heat panel was installed in each end of the quonset building. The thermostats for these heat panels were set at 60 F for the first week; then reduced to 50 F.

TABLE 1. TEMPERATURE AND RELATIVE HUMIDITY FOR BROODING PERIOD FEB. 27 - APR. 29, 1951

Location	Temperature, deg F			Per cent relative humidity		
	Avg max	Avg min	Mean avg	Avg max	Avg min	Mean avg
Insulated house (near ceiling)	72.4	53.4	62.9	71.6	48.3	60.0
Insulated house (2 ft above floor)	69.1	51.5	60.3	82.0	56.5	69.7
Uninsulated house (2 ft above floor)	71.7	51.3	61.2	90.4	40.4	65.4
Ambient	58.2*	39.6**	48.9	89.6	39.4	64.5

*Minimum ambient, 23 F. **Maximum ambient, 78 F.

RESULTS AND DISCUSSION

Temperature and Relative Humidity in Colony Houses. The data in Table 1 show a summary of the temperature and relative humidity for the two small houses. Even with the ventilating fan operating, there was a slight differential in temperature and relative humidity between 2 ft above the floor and near the ceiling in the insulated house. The average minimum ambient temperature was 39.6 F. The minimum ambient temperature during the brooding period was 23 F and the maximum was 78 F. Cloudy and inclement weather prevailed during most of the brooding period. Upon first observation it would seem that the mean average temperature in the uninsulated house should be lower than the mean average temperature in the insulated house. The fact that there was more heat loss in the fan-exhausted air in the insulated house must be considered when this comparison is made. The latent heat of evaporation of moisture from the litter also caused the temperature in the ventilated house to be lower.

Assuming that a temperature of 60 F is to be maintained in each house with an ambient temperature of 20 F, calculations presented earlier show that it would require 8975 Btu per hr for the uninsulated and natural-ventilated house and 3447 Btu per hr for the insulated and mechanically ventilated house. The energy produced by three 250-w heat lamps burning continuously for one hour would be 2650 Btu. During this test the ambient temperature did not remain at 20 F for any great length of time and it was possible to maintain a comfortable energy level over most of the test period without any supplemental heat. As the chicks grow older the energy that they liberate assists in keeping the house warm; however, this energy was neglected in above calculations.

Electrical Energy Consumption and Mortality. Table 2 presents a summary of electrical-energy consumption and mortality. The energy required during the 8-week brooding period for the insulated and ventilated house was 1.92 kw-hr per chick, while the energy per chick for the uninsulated house was 1.68 kw-hr per chick. The insulated house required more energy per chick due to fact that more heat was lost through the fan exhaust air. A small amount of energy was also required to operate the fan motor.

During the third and fourth week the power was cut off at irregular intervals at night in order to study the actions of the chicks during a power outage. The instant the house became dark, the chicks began to chirp very loudly, then, after a few minutes, they would begin to wander blindly through the house and would tend to pile up in small groups in corners and near the feeding hoppers.

The energy consumption per chick for the quonset building was 3.76 kw-hr. This is higher than in previous years and includes approximately 0.20 kw-hr per chick for supplemental heat and approximately 0.15 kw-hr per chick for the ventilation-fan motor and ceiling lights. The fact that 550 fewer chicks were brooded in the quonset building in 1951 than in previous years accounts for much of the increased energy consumption per chick. The infrared lamps remained on continuously for the first three weeks, after which they were controlled with a thermostat. If the lamps had remained on continuously for the entire brooding period, the energy consumption per chick would have been about 3.78 kw-hr. This is slightly more than the figure above, and shows that by installing the thermostat, energy equivalent to that required for supplemental heat, ventilation and ceiling lights was saved.

The mortality at the end of 8 weeks of brooding was 1.0, 1.5, 9.4 per cent, respectively, for the insulated house, uninsulated house and quonset building. At the end of 8 weeks the chicks in the two small houses appeared to be doing better

TABLE 2. SUMMARY OF ENERGY CONSUMPTION AND MORTALITY

	No. chicks started	Date started	Kw-hr per chick	Per cent mortality at end of 8 weeks
Insulated house	200	2/27/51	1.92*	1.0
Uninsulated house	200	2/27/51	1.68	2.0
Quonset building†	1170	5/14/51	3.76‡	9.4§

*Includes approximately 0.18 kw-hr per chick for ventilation fan controlled by thermostat.

†Practically all chicks inbred 12.5 per cent or more. No inbred chicks in colony houses.

‡This includes 0.20 kw-hr per chick for supplemental heat and approximately 0.15 kw-hr per chick for ventilation fan and incandescent lights.

§Includes 1.4 per cent mortality due to coccidiosis. No coccidiosis in colony houses until after 8 weeks.

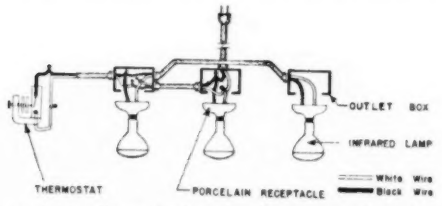

FIG. 6. Wiring diagram for hover brooder using 2-conductor No. 12 non-metallic cable.

than any other group of chicks at the poultry plant and the pullets were moved to range houses while the cockerels remained in the original houses. The infrared lamps were turned off at the end of 8 weeks. The litter was changed at the end of 8 and 10 weeks. At the beginning of the ninth week, the cockerels developed coccidiosis. The weather was cool and the houses were damp during this period. The infrared lamps were turned on during this period of sickness, and the drinking water was treated with sulfamethazine. Between the eighth and tenth week twenty-one of the cockerels died in the uninsulated house and fourteen cockerels died in the insulated house as a result of this disease. Ten died of coccidiosis between the eighth and tenth weeks in the quonset building. The pullets that were moved to other houses were not affected by coccidiosis.

TABLE 3. SUMMARY OF MOISTURE CONDITIONS IN LITTER FOR TWO COLONY HOUSES

	Per cent moisture (wet basis)					Litter changed
	4 wk	5 wk	6 wk	7 wk	8 wk	
Fan-ventilated, insulated house	29.5	31.6	37.5	45.6	New litter	End of 8 and 10 weeks
Natural-ventilated, uninsulated house	26.6	41.1	45.9	48.7	New litter	End of 8 and 10 weeks

Litter and Ventilation. A summary of litter conditions for the two small houses is shown in Table 3. The data in this table show that the moisture in the litter increased, as the chicks grew, to a minimum of 45.6 per cent for the mechanically ventilated house and 48.7 per cent for the natural-ventilated house. The litter was first changed at the end of eight weeks. The litter probably should have been changed at the end of the fifth week due to high moisture; however, the moisture in the first litter was allowed to accumulate in order to study the effect of the two ventilation systems on litter-moisture content. There was not sufficient ventilation in either house to keep the litter dry. From the fifth to seventh week the litter in the fan-ventilated house was consistently lower in moisture content than in the natural-ventilated house. Condensation was observed on the walls of the natural-ventilated house when the windows were not open to the maximum of a 10-in tilt at the top of the window. No condensation was observed on the walls or windows of the fan-ventilated house after the fan was placed in operation. There did not appear to be any condensation of moisture on the surface of the floor under the litter of the insulated house. Some condensation was observed under the litter outside the area where energy radiated on the litter in the house with uninsulated floor. Apparently most of the moisture in the litter was from droppings and water from drinking containers. The odor of ammonia was strong in both houses after the fifth week.

The consistent increase of moisture in the litter can be attributed to a combination of two factors — too many chicks in the 110-sq-ft area and insufficient ventilation. There was about 0.55 sq ft of floor area per chick for the first 8 weeks. A minimum of 0.75 sq-ft per chick would probably be better. Of course, if more floor space is available per chick, the litter will be kept in better condition. The fact that the air had to enter through a 180-deg entrance baffle and turn through two 90-deg sections of the exit duct lowered the capacity of the ventilation fan in the insulated house. With recent published material available (6) relative to air flow through ventilation air entrances, future installations can be more accurately designed. Based on preliminary air-stratification studies with smoke in the ventilated house, the fan would probably have been more effective if it had been placed on the opposite side of the house from the windows.

The inside volume of the two small houses is approximately 660 cu ft. It is estimated that less than one cubic foot of air per minute per bird was moved when the fan was on. If the fan remained on continuously the air currents or drafts kept the chicks uncomfortable, especially at night when the outside humidity was high. Due to this fact, the fan was controlled by a thermostat set at a temperature of about 5 deg above the water thermostat that controlled the infrared lamps. When this was accomplished the chicks appeared to be more comfortable as long as the outside temperature was below 60 F. Some compromise will generally have to be made on the maximum air flow that would be desirable to keep litter dry and the minimum of air currents allowed to prevent drafts on the chicks. If a relatively large amount of cold air is moved through the house, this will cause the thermostatically controlled lamps to cycle more often. When the outside temperature was 75 F or above, the chicks were not comfortable even with the fan on continuously. Windows and doors were opened for better ventilation.

The litter in the quonset building remained in relatively good condition through the brooding period and was not changed. There was approximately 0.64 sq ft floor space per bird in the quonset building. The 1650-cfm fan appeared to ventilate the quonset building properly with 1170 birds as long as the outside temperature was below 60 F. The temperature control of the ventilation fan was generally set 3 to 5 deg above the setting on the thermostat that controlled the infrared lamps. When the outside temperature was above 75 F, doors and all end windows were opened in order to prevent the chicks from spreading their wings and becoming uncomfortable due to insufficient ventilation. The ventilation characteristics of the quonset building, where considerably more cubic feet of air space is available per chick, appear to be quite different from the ventilation characteristics of the two small houses. The litter in the quonset building remained in better condition when compared with the other two houses.

Hovers and Baffles. The purpose of the hover or baffle is to reduce convection currents over the birds and give protection to the lamps. The horizontal baffle used is easier to construct than the hover-type brooder, however, this type of unit does not give as much protection to the lamps. The individual hover unit (Fig. 4) has proven to be satisfactory for three brooding seasons. When the temperature in the house falls below 45 F, if a hover is not used, in order to keep chicks comfortable, the number of chicks per lamp (1) should be reduced about 25 per cent. In other words, when the lamp arrangement as shown in Fig. 3 (no hover) is used, more watts per chick brooding capacity is required. Also, with no hover the chicks must be more closely observed during low-temperature periods so that the energy on the chicks may be increased. If this is not done, drafts created around the heated area are likely to cause the chicks to pile up in an effort to keep comfortable. With a hover this piling up and crowding under the lamp was reduced.

The hard-glass or heat-resistant-type lamp has proven to be more satisfactory when a hover is not used. When a hover is used, the non-heat-resistant lamp may be used because the hover offers some protection for the bulb from breakage.

Physical Observations. The feathering of the chicks in all three houses appeared to be normal for the 1951 season. There was no statistical difference between the rate of weight gained of chicks brooded with infrared energy and those brooded with other systems. The pullets from the two small houses will continue under observation to ascertain the age of sexual maturity and size and number of eggs laid over a given period. The statistical analysis of part of the egg production for the 1949-50 broods showed that there was no significant difference between the size of eggs or number of eggs laid between the infrared brooded flocks and the flocks that were brooded with other systems.

SUMMARY

1 The energy consumption for the first eight weeks for the insulated and mechanically ventilated house, uninsulated house and quonset building was 1.92, 1.68 and 3.76 kw-hr per chick, respectively, as compared with about 0.5 kw-hr per chick for conventional electric brooding, while the mortality for these same houses for the first 8 weeks was 1.0, 2.0, and 9.4 per cent, respectively.

2 For the first eight weeks the chicks in each of the three houses grew rapidly and uniformly. They ate and slept in 24-hr shifts and sought the comfort level under the lamps to suit individual needs. Each chick is his own thermometer. Infrared does not register on a ther- *(Continued on page 20)*

Effect of Heat Blanching on Alfalfa

By C. Ray Thompson

ALFALFA, because of its high yield of protein, provitamin A (carotene), other vitamins, minerals and palatable roughage is the pre-eminent forage crop of the United States. However, most of the crop (97 per cent) is field cured under conditions which may cause major losses of carotene, protein, and soluble nutrients up to 30 per cent of the dry weight (1)*. Dehydration minimizes nutrient losses but transportation, fuel and labor cost is about $25 to $30 per ton.

Previous studies (2) showed that steam blanching alfalfa reduced carotene loss during drying. Probably this was caused by inactivation of enzymes, and presumably the same treatment would prevent carbohydrate and protein losses caused by the plant continuing to respire for several hours after being cut.

These considerations led to the conclusion that perhaps some of the benefits of dehydration could be realized if alfalfa were cut and the plants killed by heat, after which they could be dried as is done in ordinary field-curing practice.

Methods. Two experimental "heat blanchers" were used. The first consisted of two steel plates ¼ x 18 x 18 in hinged at one edge with a handle on the opposite edge for lifting one side. The apparatus was heated to 165 C and green alfalfa was inserted for two seconds.

A more continuous type of heat-blancher was designed later. This consisted of two horizontally disposed, hollow steel rolls 6 in in diameter by 24 in in length which were supported on a steel frame and were driven by gears and a sprocket chain at one end. A spring tension maintained pressure on one roll so that material passing between the rolls was compressed. The rolls were heated by gas burners with a large jet inside the rolls and a series of small jets on the lower outside of the rolls (Fig. 1).

In operation the rolls were driven at a speed of about 3 rpm by a ½-hp electric motor geared through a speed reducer. Scrapers were provided to bear against the lower side of the rolls to remove any adherent material before it became badly scorched. The alfalfa was fed down an inclined apron so that it passed between the rolls.

Carotene determinations were made by the method of Zscheile and Whitmore (3). In "control" samples where complete retention of carotene was desired, samples of green alfalfa were steam blanched at 5 lb per sq in (108 C) for one minute. Drying was completed at 60 C in a vacuum oven.

Experimental. Previously reported studies (2) showed that steam blanching of alfalfa resulted in greater retention of carotene during drying, but prolonged heating gave comparably greater losses during storage. To test the effect of both heating and crushing on the rate of moisture loss of green alfalfa the following studies were carried out. Eighteen samples of 10 stems each of mature alfalfa were selected. The samples were divided into three lots of six each and the lots were treated as follows: (a) control, (b) heat blanched between plates, and (c) rolled between 3-in-diameter rubber rolls to crack open the stems. Gross examination indicated about equal crushing in both heat-blanched and rolled samples. All samples were then distributed randomly in a drying oven and were dried at room temperature in the dark by means of the circulating fan. The samples were weighed after 2, 4, 7, 10, and 26 hr of drying. The results (Table 1) showed that about 17 per cent of the original or fresh weight was evaporated in heat blanching. However, even when the initial loss of moisture was neglected, calculations showed that the heat-blanched samples dried more rapidly than the controls and slightly faster than the rolled samples, indicating that the heating, by some gross cell alteration, caused an increased rate of water loss. Also, the heat-blanched samples retained about 50 per cent more carotene than the controls. Cracking of the stems by rolling, while speeding drying, did not favor carotene retention.

TABLE 1

Drying time, hr	Control, % orig. wt	Heat Blanched % orig. wt	Heat Blanched % blanched wt *	Rolled % orig. wt
2	70.7	61.5	74.1	73.0
4	62.3	48.4	58.6	61.9
7	51.9	34.7	41.9	44.8
10	43.7	27.8	33.6	34.2
26	23.1	21.5	26.0	21.4
Carotene, ppm	245 ± 19	366 ± 20		217 ± 11

*82.7 per cent original wt. Avg. std. dev. of % = ± 2.0

To study further the effect of heat blanching, especially the effect of temperature of the rolls during blanching on carotene retention during drying and later storage, 28 samples of mature alfalfa stems, 200 g each, cut to 20-in length, were divided into seven lots of 4 samples each. One lot was steam blanched and vacuum dried while a second lot was sun dried. The remaining five lots were heat blanched at successive temperatures of 230, 240, 250, 260 and 270 F with the heated rolls. The heat-blanched samples required one day for drying in the sun while the untreated samples required two days.

The results (Table 2) showed that heat blanching served to preserve carotene and speed drying. Optimum temperature range seemed from 230 to 250 F under these conditions. The storage stability of the samples was determined at 65 C for 14 days and the results calculated on the basis of the carotene present in the *dried material*. These results showed that the

TABLE 2

No.	Treatment	Carotene retained, ppm	Per cent of original remaining	Storage stability (per cent of carotene in dried sample)*
1	Steam blanched vacuum dried	243 ± 12	(100)	28
2	Sun dried	53 ± 9	21	21
3	Heat bl, 230 F	193 ± 12	79	51
4	Heat bl, 240 F	178 ± 25	73	52
5	Heat bl, 250 F	190 ± 3	78	52
6	Heat bl, 260 F	166 ± 7	68	52
7	Heat bl, 270 F	162 ± 12	67	50

*65 C for 14 days

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*Numbers in parentheses refer to the appended references.

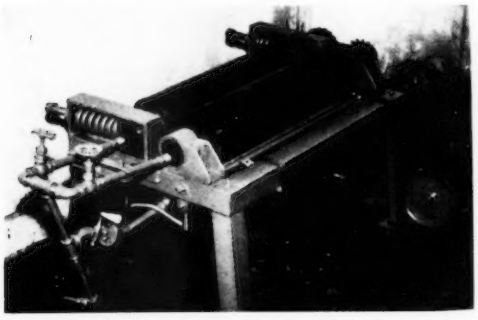

Fig. 1. Experimental heat-blanching rolls

carotene in the steam and heat-blanched samples was more stable than in the sun-dried samples during storage, although not to a marked extent.

DISCUSSION

These studies have shown that heat blanching alfalfa, prior to field drying, speeds moisture loss and would serve materially to reduce the drying time. This would minimize the possible damage caused by rain and heavy dew which leach out soluble nutrients besides providing excess moisture which results in undesirable bacterial or mold growth. It also preserves carotene probably by inactivating destructive enzymes and reducing the time of exposure to high light intensity in the field. The heat blanching should also prevent losses of nutrients which are ordinarily consumed by the respiration of the plant from the time of cutting until respiration ceases. These have been estimated to be from 5 to 10 per cent of the total dry weight. It gives a dried product in which the carotene is more stable than in ordinary sun-dried hay. This may be caused by the heat disrupting the organization or structure of the cell so that naturally occurring antioxidants such as tocopherols and other compounds(2) are brought into mutual solution with the carotenoids.

Because the water in the plants needs only to be brought to near boiling and not evaporated, the calories of heat required for blanching would be, theoretically, only 12 per cent of that used in dehydration. In practice this would perhaps be about 25 per cent because of some evaporation caused by local overheating.

One disadvantage of heat blanching was the pronounced bleaching of stems exposed to light during drying. This gave a partially bleached hay and when ground a mottled-colored meal. However, a leaf meal could be prepared which would have a good color.

At present no machine is available commercially for performing this operation in the field, but it is suggested that an apparatus could be devised, similar in design to the John Bean "Haymaker," in which the rolls would be heated by gas or oil flames to give the desired heat blanching of the product. If a field-operated machine such as this can be devised, it promises to produce a forage which is superior to presently produced sun-cured alfalfa and avoid the extended period of drying now necessary with the incident uncertainties of bad weather which now plague the producer.

SUMMARY

These studies have shown that heat blanching of green alfalfa speeds sun drying by increasing the rate of water loss, and preserves carotene. It also gives a product in which carotene is more stable than in ordinarily dried material and probably preserves nutrients ordinarily lost by respiration after cutting.

A design for a machine is proposed which will accomplish this operation.

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Brooding Poultry with Infrared Energy

(*Continued from page 18*)

mometer. Chicks that were under an adequate amount of infrared were calm and spread out evenly.

3 Up to eight weeks, all of the birds in the two colony houses grew and feathered normally. After eight weeks, the cockerels which were retained in the original houses suffered severely from an outbreak of coccidiosis (even though the houses were thoroughly dry-cleaned and fresh litter introduced). On the other hand, the pullets which were transferred to other houses continued their excellent development. The drier litter and decidedly lower incidence of coccidiosis in the quonset building were probably due to a higher amount of air infiltration and also to the greater volume of air per chick due to the high ceiling and possibly due to the small amount of supplemental heat used. Since the infrared lamps did not heat the surrounding air directly, the accumulation of moisture in the litter was permitted.

The two experimental brooding units (Fig. 5) were constructed and radiant heat patterns determined. These units will be used for future brooding studies. The three-lamp hover unit was designed for a capacity of from 200-250 chicks and the six-lamp unit to have a capacity of about 400-450 chicks.

4 These results point out the need for reducing the cost of operation of infrared brooding. One of the greatest problems with infrared brooding as with most any method of brooding is proper ventilation and litter management. Also, especially in small houses, either a larger ratio of chick to floor space is needed, or perhaps, warm-air ventilation is required. In either case, the cost would be increased. In addition, from the results of these tests the costs of litter management in the small houses with no supplemental heat is much higher than in similar houses using coal or wood burning brooders.

5 In larger houses with greater volumes of circulating air per chick, the difficulties with ventilation and damp litter are not so great.

6 As a result of power outages made at night, the initial effect, due to a loss of light, was for the chicks to chirp loudly and wander blindly over the house. Then as a result of loss in heat they would begin to pile up near feeding hoppers and in corners. A stand-by lighting system, together with a battery alarm, would be good insurance in case of an outage.

7 Based on the results of these tests, it is desirable to have the infrared lamps mounted under a hover or baffle to reduce convection currents around the heated area and to protect the bulk from mechanical breakage. When a single lamp is used with no hover for small broods, the hard-glass bulb will be more satisfactory. When a hover is not used, generally about 25 per cent fewer chicks can be brooded per lamp. The non-heat-resistant bulb proved to be satisfactory with a hover.

8 A dial-calibrated wafer thermostat would be a convenience for controlling the infrared lamps so that it will not be necessary to recalibrate the wafers each time one is reset.

9 There was no statistical difference between the rate of weight gained (for 1949-50-51), size of eggs, or number of eggs laid (for 1949-50) for the infrared brooded flock and those brooded with wood and coal brooders.

10 Pullets from the 1949-50 infrared brooded flocks began to lay 2 to 3 weeks before their 1, 2 and 3-weeks older sisters that were brooded with other systems. The chicks brooded with infrared lamps had light 24 hr each day for the first eight weeks, while their sisters brooded with other systems had no light at night. This may have caused the earlier maturity in the infrared brooded flock. However, after the first eight weeks, neither group had artificial light at night.

These studies will be continued in an effort to correlate the regulation of energy output of the infrared lamps with ventilation and litter management so that operating costs may possibly be reduced. The optimum radiant-energy level for brooding chicks will also be further investigated.

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Application of Universal Joints to Farm Machinery

By Fred M. Potgieter
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IT IS always interesting to know a little of the history and background of any mechanical device, so I will open this paper on the design and application of universal joints with a brief history of the development of the Cardon universal joint as we now use it. In an architect's sketch book of the 15th century there is a drawing of a two-axis joint and this description: "You construct a kind of apple of brass in two halves which fit together like two circles which have two pivots each and in the middle place a brazier with two pivots. The pivots must be placed in contrary directions so that in all positions the brazier may remain upright. If you make two contrivances exactly as the description and drawing shows it, you may turn it about in any way and the brazier will always be level and the cinders will not fall out."

In other words, the first universal joints were apparently used to suspend a brazier full of red hot coals so that, when it was carried about suspended by this universal joint, it always stayed level and the cinders did not fall out. Later these joints were termed in old English as gimmals from the French word for twins and literally means two hinges in one. In the 15th century these gimmals were used in the construction of carriages so that the body of the carriage was suspended from its framework by gimmals. If the carriage turned over, the body would stay upright. Apparently the first man to devote a great deal of study to universal joints was an Englishman, a Mr. Hooke, who was curator of the Royal Society in London in 1662. In 1664 he took out several patents covering applications of universal joints. The French attribute the universal joint to Mr. Cardon who lived in the 16th century. His technical papers illustrate the same universal joint for suspending a brazier or lamp. The work these two men did on universal joints leads to the joint being known as a "Hooke" or "Cardon" joint.

The next application of universal joints we can find any record of was for driving the hands of a clock from a remote clock works. In this connection Mr. Hooke pointed out that it was necessary to use a pair of universal joints with equal angles in order to have uniform angular velocity of the clock hands. The first application of universal joints in pairs was apparently made in 1683 by Mr. Hooke, who, by the way, was quite a mathematician.

The earliest known application of universal joints in a farm machine was in a machine for sowing seed patented in England on July 30, 1784, by a Mr. Wright. In 1804 a Mr. Gray published a book in England titled "Experienced Millwright" which described universal joints and their application. In 1870 Robert Willis of London published a book "Principles of Mechanism" which devoted two chapters to universal joints and their application and theories. Mr. Willis covered the mathematics very carefully and developed formulas showing the fluctuations in angular velocity due to angles in the joint. Mr. Willis' book is recommended as very interesting reading.

The most common universal joint in use today in farm machines is the Cardon or Hooke joint as shown in Fig. 1. This joint consists of two yokes which attach to the shafts and each yoke is designed to take two bearings. Between these yokes and connecting them is a cross and four bearings — two bearings in each yoke. The total torque transmitted in the joint is carried by one pair of bearings so the pounds load in each bearing in a universal joint is the torque transmitted expressed in inch-pounds, divided by the distance expressed in inches between the two bearings in one yoke. In a roller-bearing universal joint this load may be many thousands pounds per square inch of projected area of the roller bearing. This value depends on the speed and angularity of the particular application and the life expected. In a plain-bearing joint this unit load figure is much lower, and, therefore, plain-bearing joints for the same capacity have much larger bearings and trunnions, and the joint is much larger and heavier.

A universal joint usually has another function than transmitting rotary motion; it must support the shaft that is attached to one yoke member of the joint, or, in the case of a double-joint application, it must support the shaft or tube between the two joints. This necessitates a thrust bearing in each of the trunnions of the joint as well as a radial bearing. This is usually accomplished by grinding the ends of the

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Fig. 1. The Cardon or Hooke universal joint most commonly used in farm machines

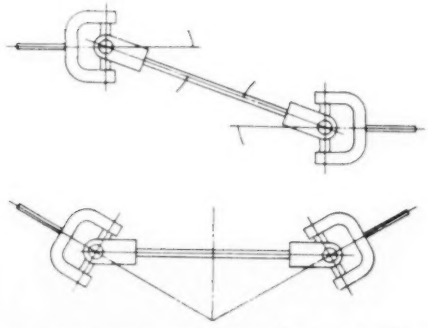


Fig. 2. Universal joints are normally mounted in pairs with equal angles in the joints and with the yokes in line, and the shafts all in one plane or parallel planes

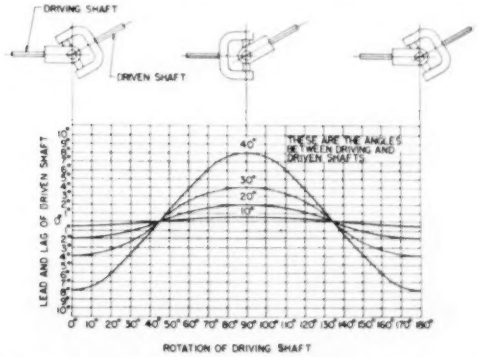

DRIVING SHAFT
DRIVEN SHAFT
THESE ARE THE ANGLES BETWEEN DRIVING AND DRIVEN SHAFTS
40°
30°
20°
10°
LEAD AND LAG OF DRIVEN SHAFT
0° 10° 20° 30° 40° 50° 60° 70° 80° 90° 100° 110° 120° 130° 140° 150° 160° 170° 180°
ROTATION OF DRIVING SHAFT

Fig. 3. The curves show the values of lead and lag of the driven shaft of a universal joint, ahead and behind the drive shaft

Fig. 4 (*Left*) This typical application of a pair of universal joints shows the steering joints of a farm tractor. • Fig. 5 (*Right*) This shows the drive on a corn picker where the universal joints compensate for misalignment to the 22-deg angle of the snapping rolls.

trunnions of the center cross and the bottoms of the cups of the bearings thereby forming a plain thrust bearing (Fig. 1). This thrust bearing is adequate as it is well lubricated. The centrifugal force of the rotation of the joint keeps these plain surfaces flooded with lubricant.

In applying a Cardon universal joint to a drive it is important to provide for end movement of the shafts to which the joint is attached as the joint in itself is rigid endways. Any end movement, even a small amount, caused by a deflection of the machine or temperature changes must be provided for in some manner. This is usually accomplished by telescoping shafts and tubes or splined connections. This sliding connection is normally furnished with the joint and engineered by the joint manufacturer to fit each application. If this sliding connection is between the two joints, it is advisable to so design it that it cannot be assembled wrong, that is, with the joints out of proper phase. This can be accomplished by using rectangular tubes and shafts or by providing a groove in the square shaft with an interference pin in the square tube or in splined connections by providing a blind spline. This construction is necessary to insure the yokes of the two joints being in the same plane as shown in Fig. 2.

THE GENERAL PROBLEMS OF UNIVERSAL-JOINT APPLICATION

The mathematics involved in a Cardon universal joint have been known for a long time, but they are not generally understood. The first problem is the use of a single joint in a machine application. It can be assumed that the joint will be operated at some angle, or it wouldn't be used. A single Cardon universal joint operating at an angle will not deliver uniform angular velocity. At low angles, say, less than 10 deg, this is usually not serious unless the rotating element of the machine includes flywheels or parts with a large WR^2 that will resist the fluctuations in angular velocity. The curves in Fig. 8 show these values as lead and lag of the driven shaft, ahead and behind the drive shaft. These curves are based on the formula, $\tan Y = \tan X / \cos A$, when Y equals the angular displacement of the driving shaft, X the angular displacement of the driven shaft, and A the angle between the two shafts. This curve shows what happens for one-half revolution of the driving shaft, and the same thing is repeated in each half revolution. It will be noted that at a 10-deg angle between shafts the lead and lag become 8 deg each or a total fluctuation of 16 deg. If the drives in the machine are rigid, such as gears and chains, these fluctuations are more serious than if the drives are V belts or flat belts. Angular fluctuations can also be absorbed by using a long slender shaft with torsional windup in the drive.

Universal joints are normally mounted in pairs as shown in Fig. 2, with equal angles in the joints and with the yokes in line and the shafts all in one plane or parallel planes. In this type of application the fluctuations in angular velocity of the second joint wipes out the fluctuations of the first joint and the final shaft again has uniform rotation, but the shaft between the joints will have a fluctuating angular velocity depending on the angle in the joints. It is important to keep the weight of this intermediate shaft to a minimum to avoid vibration. Therefore, the connecting shaft between the joints is usually a tubular member. If a pair of shafts connected by a pair of universal joints and intermediate shaft are not all in one plane or parallel planes, then the yokes attached to the intermediate shaft should not be in line; but should be turned out of phase with each other as much as the angle between the planes of the two end shafts. This will cause the pair of joints to give uniform angular velocity to the final shaft.

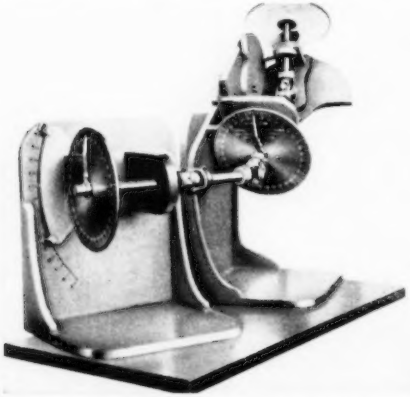


Fig. 6 Device which duplicates the final setup as to joint angles and plane angles when three or more universal joints are used in a train

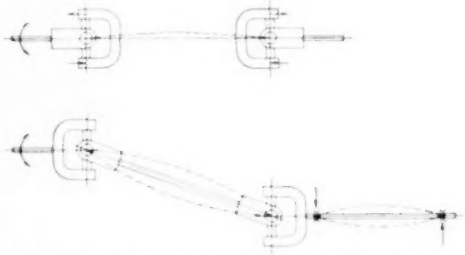


Fig. 7 This shows how a secondary load in universal joint application puts a bending moment on the connecting shafts and an additional load on the supporting bearings

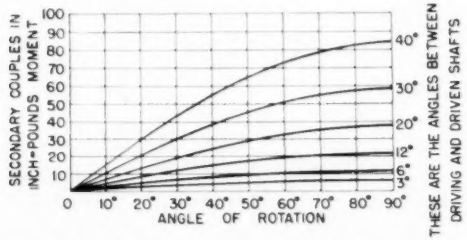


Fig. 8 Values of secondary couples for 100 in-lb of input torque

RPM	TUBE SIZE O D INCHES					
	1-1/4	1-1/2	2	2-1/2	3	3-1/2
500	70	75	80	80	90	100
600	70	75	80	80	90	100
700	65	70	80	80	90	100
800	60	70	80	80	90	95
900	60	65	75	80	85	95
1000	60	65	75	80	85	90
1200	60	60	75	80	85	90
1400	60	60	70	75	85	90
1600	57	60	70	75	85	90
1800	52	60	70	75	85	90
2000	50	58	70	75	85	90
2200	46	55	66	73	83	90
2400	43	51	62	70	79	86
2800	40	49	60	67	75	83
2800	38	46	57	65	72	80
3000	36	44	55	62	69	77
3200	33	42	52	60	67	74
3400	32	40	51	58	64	71
3600	30	38	49	56	62	68
3800	28	36	47	54	61	66
4000	27	35	45	52	60	64

Fig. 9 This table of maximum speeds and lengths of tubular shafts is based on the experience of the author's company. It is intended as a guide only, and not as the final maximum, which can vary appreciably depending on the type of application

Fig. 4 is a typical application showing the steering joints of a farm tractor. It will be noted that the plane through the two shafts in the forward joint is approximately at right angles to the plane through the two shafts of the rear joint and that the yokes welded to the intermediate shaft are approximately at right angles to each other. Fig. 5 shows the drive on a corn picker where the joints compensate for misalignment to the 22-deg angle of the snapping rolls with the horizontal and also accommodate an offset. It will be noted that these joints are about 30 deg out of phase which is the angle between the planes through the shafts in each joint. When three or more universal joints are used in a train, the problem is studied with a device (Fig. 6) which duplicates the final setup as to joint angles and plane angles. Then by experiment the optimum setting of the joints is obtained.

It is difficult to give any limits of angularity of universal joints as applied to drives. In the case of one application an extreme angle of 67 deg, at 500 rpm power take-off speed, is used momentarily, but that is an unusual condition and is not recommended. Ordinarily the angles should never exceed 45 deg per joint when the joints are used in pairs, and 15 or 20 deg for single joints. This angle depends on the type of drive, the WR^2 of the rotating parts, the flexibility of the rotating parts, and the speed and life expected.

One of the problems of universal joint application that is little understood is that of the secondary loads due to angularity of the joint and how they are transmitted to, or resisted by, the shafts to which the joint is attached. If one will

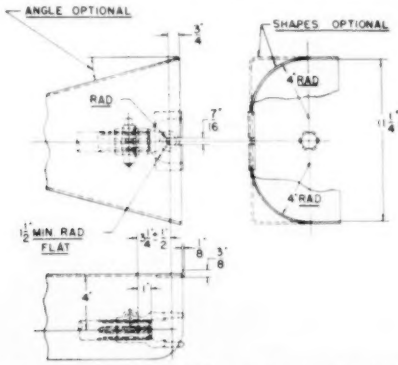


Fig. 11 Details of the ASAE standard tractor safety shield

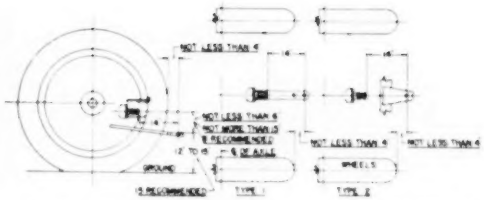
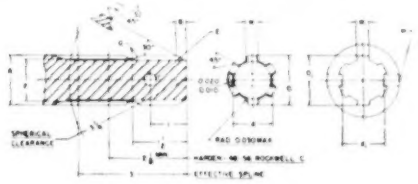


Fig. 10 Details of the ASAE standard power take-off and drawbar hitch location

imagine that a joint, operating at an angle and transmitting torque, will tend to eliminate its angle — that is, it moves the connecting shafts so that the angles in the joint will tend to become 0 deg — he will have an understanding of the secondary load problem. This secondary load puts a bending moment on the connecting shafts and an additional load on the supporting bearings as shown in Fig. 7. In this drawing the dotted lines show the bending effect on the shafts and the arrows show the direction of the load applied to the bearings. These loads fluctuate twice every revolution of the shaft and reverse in direction the same as the fluctuation in angular velocity. The maximum value of these secondary couples for various angles are shown in the curves Fig. 8. These curves are based on 100 in-lb of torque at various angles in the joint from 5 to 40 deg. They show the value of the secondary couple for one-fourth revolution of the joint during which the value of the secondary couple goes from 0 deg to a maximum. The peak of each curve is the maximum secondary load that will be reached for that torque and angle in the joint. For example, a single joint at a 40-deg angle transmitting 100 in-lb will exert a bending moment of 85 in-lb in the attached shafts. Assuming the bearings supporting the attaching shafts to be spread 2 in, the added bearing load would be 85 divided by 2, or 42½ lb per bearing. It will be noted that this is considerable. These secondary couples also make it advisable to attach universal joints to their shafts with long hubs and tight fits, and to see that they are securely clamped. A universal joint should be attached to its shaft as firmly as a crank



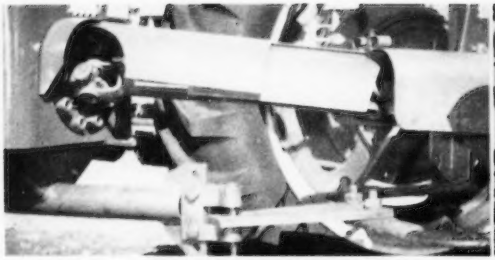
Shaft and Hub Spline Dimensions

A Nominal Diam	SPLINE ON SHAFT						SPLINE IN HUB					
	D Large Diam		d Small Diam		W Spline Width		D1 Large Diam		d1 Small Diam		W1 Spline Width	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1-3/8	1.373	1.371	1.108	1.098	0.340	0.338	1.375	1.374	1.170	1.168	0.344	0.342
1-3/4	1.747	1.745	1.427	1.417	0.433	0.431	1.750	1.749	1.489	1.487	0.438	0.436

General Shaft and Hub Dimensions

C Radius	E Hole Diam.	SHAFT F Groove Bottom Diam.		B Chamfer Length	Pin Diam.	Hub Pin Hole Diam.
		Max.	Min.			
17/64	21/64	1.160	1.155	9/32	5/16	21/64 0.328
21/64	25/64	1.470	1.465	11/32	3/8	25/64 0.390

Fig. 12 The spline-shaft dimensions of the ASAE standard tractor power take-off shaft



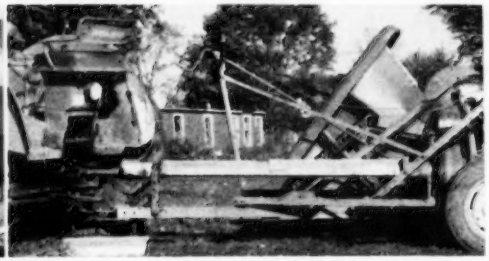


Fig. 13 (*Left*) A tractor hitched to a hay baler with safety shields in place. • Fig. 14 (*Right*) A field forage harvester hitched to a tractor with the front shield removed

would be, as any looseness in this connection will soon wear out the connecting parts.

The intermediate shafts of universal joints are usually made of tubing. It is important to know the critical speeds of a tubular shafts as used in this application. The critical speed (in rpm) of tubular shafting is $(4{,}705{,}000/L^2) \times \sqrt{D^2 + d^2}$, where L = length in inches, D = outside diameter of tube in inches, and d = inside diameter of tube in inches. For safe operation the speed of tubular shafts should be from 15 to 50 per cent less than the critical speed. For speeds less than 2,000 rpm and lengths less than 72 in, a 15 per cent factor of safety may be used. For higher speeds or longer lengths a greater factor of safety should be used. These figures on maximum lengths and speeds should not be exceeded.

These critical speeds with proper factors of safety are expressed in the table shown as Fig 9. It will be noted that we do not recommend over 100-in length of a $3\frac{1}{2}$-in tube at 500 rpm which is approximately the power take-off speed of a standard farm tractor. The matter of efficiency and life of universal joints go hand in hand. Roller-bearing joints at angles less than 15 deg have an efficiency of over 99 per cent. They run cool and need very little attention with the grease gun. Plain-bearing joints, unless they are made proportionately much larger are kept well lubricated, may have efficiencies as low as 60 per cent for a single joint. If a designer is planning a quality machine — free running and with a minimum of friction and long life — he should choose roller-bearing joints just as he chooses anti friction bearings for his important drives. For steering applications the use of roller-bearing joints make it possible to maintain a minimum backlash in the joints over the life of the tractor and also makes it possible to operate at larger angles without making the tractor difficult to steer. Some steering applications have roller-bearing joints operating at angles greater than 45 deg.

SPECIFIC UNIVERSAL JOINT APPLICATIONS

The power take-off drive from a tractor to an implement is the most common universal-joint application in farm machinery. For many years the power take-off shaft of each tractor was made different. The tractor designer would put the shaft where it was most convenient, and he furnished any kind of spline, thread or taper that suited his fancy. The result was that the country was flooded with tractors with power take-off shafts, all different. This made the implement engineer's job almost impossible. If he wanted a universal joint for his PTO-driven implement, he would have to furnish or make available to the dealers and users almost 100 different attaching bundles, consisting of special universal joints and drawbar extensions, etc., in order to fit his implement to the various tractors. This wide variety made it impossible to furnish adequate shields for the power take-off shaft, which resulted in many serious accidents, the farmers getting their clothing caught in the power take-off shafts. About 10 or 12 years ago this Society, with the Society of Automotive Engineers and the farm machinery and tractor industry, brought an end to this chaos. They adopted a standard agricultural tractor power take-off shaft and drawbar attaching location and a master safety shield. This standard has been published by the American Society of Agricultural Engineers, and copies may be obtained from its headquarters office at St. Joseph, Michigan. It is recommended that every implement engineer obtain a copy of this standard for his notebook. An important part of this standard is the safety shield which is now a part of every farm tractor. The implement manufacturer is supposed to furnish a safety shield with the implement that extends from the implement up to and attaches to the standard shield on the tractor, completely covering the power take-off shaft. The standard tractor power take-off and drawbar hitch location is shown in Fig. 10. The tractor safety shield to which the implement shield must attach is shown in Fig. 11, and the spline-shaft dimensions of the tractor power take-off shaft is shown in Fig. 12.

Fig 13 shows a tractor attached to a hay baler with the safety shields in place, and Fig. 14 shows a field forage harvester attached to a tractor with the front shield removed.

In the development of new tractors and farm machines designed to conform to the above standard, the problem arose of attaching implements made in accord with the new standard to the old tractors then in use. To solve this problem each tractor company designed and made available to its dealers a package of parts which, if attached to the old model tractor,

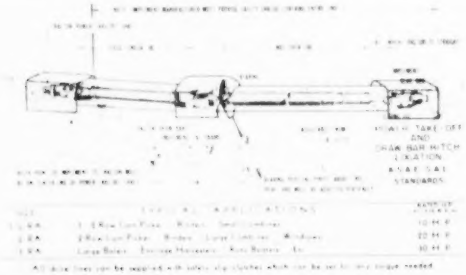


Fig. 15 A triple assembly of universal-joint hookup for a trailing implement such as a combine or corn picker

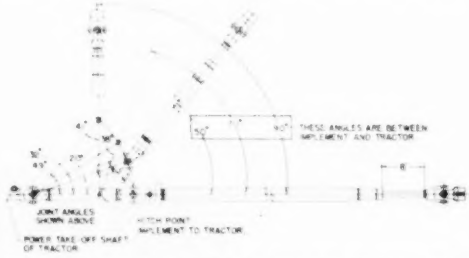

THESE ANGLES ARE BETWEEN IMPLEMENT AND TRACTOR
JOINT ANGLES SHOWN ABOVE
POWER TAKE-OFF SHAFT OF TRACTOR
HITCH POINT IMPLEMENT TO TRACTOR

Fig. 16 Plan view of the typical PTO drive with the rearbox on the implement in line with the center line of the tractor

Fig. 17 Plan view of the PTO drive with gearbox on the implement offset from the center line of the tractor

would convert the PTO shaft and drawbar to the new standard dimensions and also provide the shield on the tractor to which the implement shield is attached. The conversion bundles for a large number of the older models of tractors are all listed in ASAE Bulletin No. 41, published by the American Society of Agricultural Engineers. It is recommended that every engineer secure one of these bulletins for his notebook; copies of which may be obtained from the Society at 10 cents each postpaid.

For the average trailing implement such as a combine or corn picker, the universal-joint hookup may consist of a triple assembly as shown in Fig. 15. The 14-in dimension from the end of the power take-off shaft to the hitch point will be noted. It will also be noted that the height of the front bearing on the A frame of the implement is adjustable vertically from 8 to 15 in. This is set by the farmer to fit his tractor as the tractor PTO shaft may be from 6 to 15 in above the tractor drawbar. Our experience has convinced us that 14 in from the hitch point to the pivot on the A frame for the bearing is about right, and that a provision for 8 in slip at the rear joint is sufficient to take care of the variations in length from the tractor being straight ahead on level ground to its making a right-angle turn and going over a terrace. Also, 100 in is just about the maximum length of tubular shaft that will operate satisfactorily at power take-off speed. In this type of application the front pair of universal joints are permanently fastened together with a fixed length of 18½ in. All end movement is taken at the rear joint by the telescoping action between the solid shaft on the rear joint and the tubular shaft. The bearing on the front end of the A frame is mounted on a tipping pedestal to accommodate this end movement. In this case the front safety shield from the implement to the tractor may be a fixed length.

The table below the drawing in Fig. 15 shows the approximate horsepower required to drive various implements. These figures are intended only as a rough guide. The engineers at the John Deere Waterloo Tractor Works of Deere & Co., at Waterloo, Iowa, have made some exhaustive studies of these loads, by means of strain gages applied to the PTO shaft. These studies have resulted in some new, accurate data*.

*Paper, entitled "Loads Imposed on Power Take-off Shafts by Farm Implements," by Merlin Hansen, assistant chief engineer, John Deere Waterloo Tractor Works, presented at the winter meeting of the American Society of Agricultural Engineers at Chicago, Ill., December, 1951.

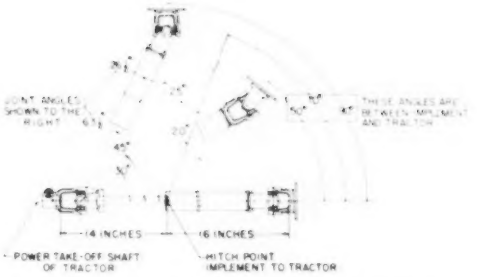

JOINT ANGLES SHOWN TO THE RIGHT
THESE ANGLES ARE BETWEEN IMPLEMENT AND TRACTOR
14 INCHES
16 INCHES
POWER TAKE-OFF SHAFT OF TRACTOR
HITCH POINT IMPLEMENT TO TRACTOR

Fig. 18 Plan view of PTO drive provided with a slip motion between the front pair of universal joints

Fig. 16 shows the typical PTO drive in plan view with the gearbox on the implement in line with the center line of the tractor. It will be noted that, when the implement is turning 90 deg to the tractor, the angles in the front pair of joints become 49 and 41 deg, which will cause the drive to be quite rough, as the angles in the two front joints are not equal and there will be serious fluctuations in angular velocity. As the field operation at this angle will be for only very short periods, if at all, the drive has proven quite satisfactory.

Fig. 17 shows the PTO drive in plan view with the gearbox on the implement offset from the center line of the tractor. If the angle between the drive line and the center line of the tractor is not more than 15 deg, this drive may be satisfactory, but it will be much rougher when turning corners in the field as the angles in the front pair of joints become 50 and 25 deg when the implement is turned at a 90-deg angle, and there will be serious fluctuations in angular velocity of the drive shaft.

On some trailing implements there is not room for the usual triple assembly between the tractor and the implement. This makes it necessary to provide a slip motion between the front pair of universal joints. The ASAE standard dimensions of 14 in from the end of the PTO shaft to the hitch point does not allow sufficient room to take care of this slip between the front pair of joints, and keep the hitch point midway between universal joints which would give equal angles at the joints at all times. But if the dimension from the hitch point to the universal joint to the implement is extended about 2 in more than the distance from the hitch point to the joint on the tractor, a fairly satisfactory drive can be worked out. This geometry would be perfect only if the hitch point was half way between the two joints, but the 14 in dimension will not allow that and provide the necessary slip motion between the joints. Fig. 18 shows the plan view of this drive. It will be noted that the angles in the joints become 63½ and 26½ deg when the implement is turned 90 deg. In this case it is necessary to provide some device in the drive to absorb the fluctuations in angular velocity that occur when turning corners. In this type of drive it is necessary to provide a telescoping safety shield over the joints from the implement to the tractor. Fig.

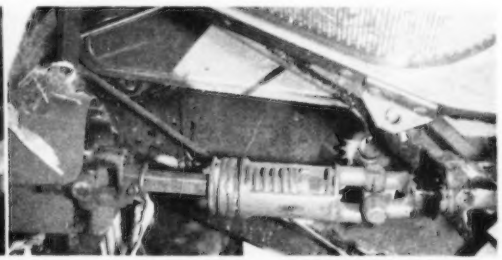
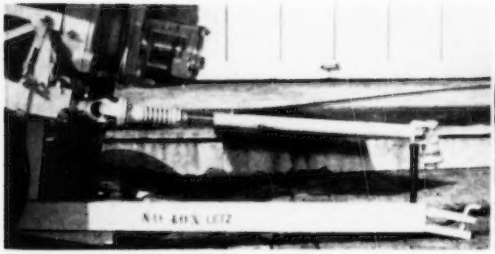


Fig. 19 (*Left*) A typical mounted corn-picker drive. Note the rectangular tube and shaft between the universal joints • Fig. 20 (*Right*) The drive on this mounted corn picker includes a slip clutch between the joints



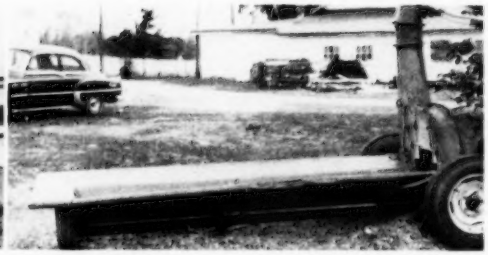


Fig. 21 (*Left*). A typical drive for feed grinders and corn shellers from the PTO shaft of the tractor • Fig. 22 (*Right*). This shows the drive for the screw conveyor in a blower

12 shows such a drive and the telescoping shield.

In mounted implements the joint hookup is usually no great problem. Fig. 19 shows a typical mounted corn-picker drive with the safety shield removed. Note the rectangular tube and shaft between the universal joints. As already stated, it is always advisable to provide some means to keep the user from assembling the joint out of phase either by rectangular slip members or with a groove in the male shaft and an interference pin in the female tube. Fig. 20 shows the drive on another make of mounted corn picker, which includes a slip clutch between the joints.

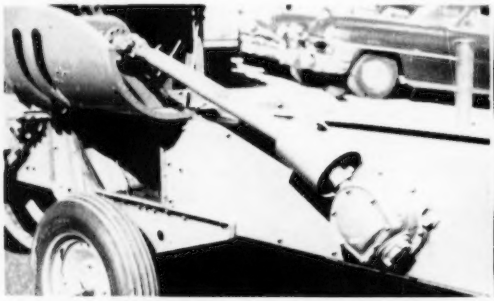
Slip clutches are often mounted in connection with universal joints, but we do not consider this construction as desirable as to mount the slip some place else on the machine as it is not good to hang so much heavy weight between a pair of joints.

Another universal joint application that is becoming popular is one that is used to drive feed grinders and corn shellers from the PTO shaft of the tractor instead of by means of belts from the belt pulley. These drives are very dangerous as users seldom place the safety shield covering the joints in place, even if it is provided, and because operators usually have occasion to work near the moving shaft. Fig. 21 is a typical example. This drive includes a slip clutch, and apparently no provision was made for keeping the joints in phase or for shielding them. A grease fitting projecting from the sleeve in the end of the tube is very dangerous.

In addition to the drives from the PTO shaft of a tractor, there are many applications of universal joints within the implements. Fig. 22 shows the drive for the screw in a blower. In this drive a long slip was provided to accommodate the difference in length of the universal-joint assembly when the blower hopper is raised. The long slip is made with a telescoping rectangular shaft and tube.

Fig. 23 shows a well-engineered drive. This drive has two joints, the lower one is covered by the safety shield. The angles in the two joints are equal and all shafts are in the same plane.

Fig. 24 shows a pair of universal joints operating at 15 deg in each joint at 600 rpm driving the sickle on a forage harvester. The large tube is the safety shield which was loosened and telescoped to show the joints. A universal joint can be used to drive a crank directly as shown in this figure, if the joint is well made and has tight bearings. A small universal



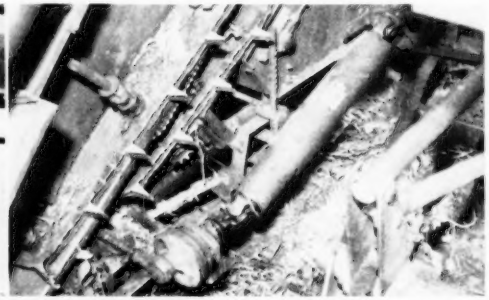
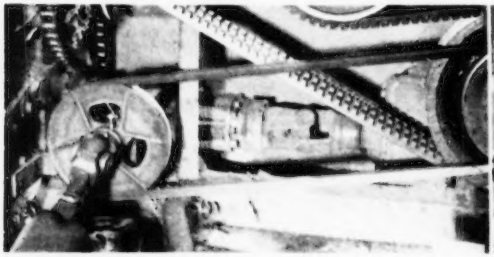


Fig. 23 (*Left*). A well engineered drive, in which the angles in the two universal joints are equal and all shafts are in the same plane • Fig. 24 (*Right*). A pair of universal joints operating at 15 deg in each joint at 600 rpm driving the sickle on a forage harvester



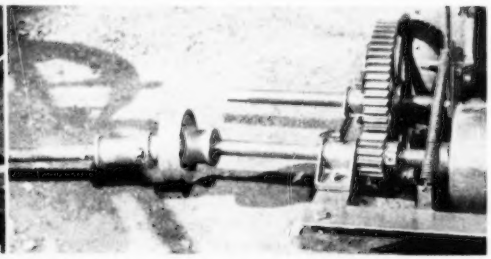


Fig. 25 (*Left*). A single universal joint and slip-clutch drive between the gearbox and pickup of a forage harvester • Fig. 26 (*Right*). The commonly known T or ring-type universal joint

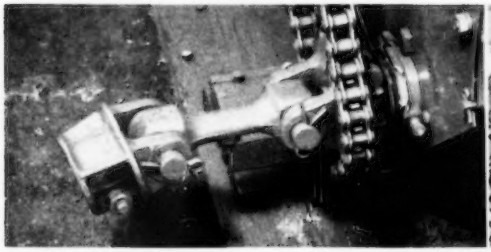


Fig. 27 (Left) A crude type of universal-joint application • Fig. 28 (Right) A common type of universal joint for small angle drives

joint will be noted at the extreme left of this figure. This joint consists of two malleable castings, a steel block, and two steel pins. It has no provision for lubrication. This joint is only satisfactory for very light loads and small angles.

Fig. 25 shows a single universal joint and slip-clutch drive between the gearbox and pickup of a forage harvester, also the rear joint of the pair of joints shown in Fig. 24.

There are other types of universal joints than the Cardon type, and I will discuss these briefly. Fig. 26 shows what is commonly known as the T or ring-type joint. In it the trunnions form a T on the ends of the driving and driven shafts and are connected by a ring. This type was formerly used on Ford and Chevrolet cars and is available as service parts for those old cars. This automotive type, made of automotive service parts, is used on some farm machinery applications where the angle is small.

Fig. 27 shows a very crude joint application. This type is satisfactory only if made very large for its application and kept well greased.

Fig. 28 shows a common type of joint for small angle drives. It is very cheap to build and if installed on the machine with the open end of the cup down, to keep out rain, water and ice, it will give satisfactory performance. The center or male member is usually made of a steel casting in the form of a cross. The only machining necessary is drilling the hole in the center of the cross for attaching to the shaft. The cup or female member is usually made of a malleable or gray iron casting with the interior shaped to fit the cross loosely. The only machine work necessary is drilling the hole for attaching to the shaft.

There are other types of universal joints, such as constant-velocity joints and Detroit ball-type joints, but discussion of these has been omitted as there is not now any application of these types to farm machinery.

This paper has touched only lightly on the many problems that arise in connection with the application of universal joints to farm machinery. The speed and power applied to farm machines is increasing and the problems of all drives are becoming greater; therefore, more attention must be given to proper engineering application.

Mathematical Analysis of the Offset Slider-Crank Mechanism

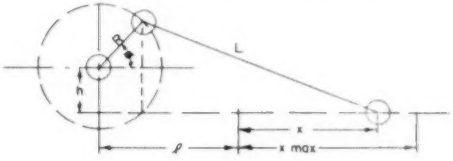
By Andrew J. Asher
ASSOCIATE MEMBER ASAE

INSOFAR as farm machinery is concerned there is a number of examples of the slider-crank mechanism as it is used for the transformation of rotary motion to reciprocating motion. The mowing machine is a classic illustration of this concept. The use of this type of mechanism may be found in some types of combines.

In the design of machinery it is well to have an idea of the velocity and acceleration at the different positions of the crankpin so that the calculations of the forces and the inherent stresses may be made. By using the Pythagorean theorem an expression may be obtained involving the displacement of the slider, the constants of the machine, and the angle of displacement of the crankpin with respect to the horizontal. By taking the first and second time derivatives of the displacement of the slider, one can obtain expressions for the velocity and the acceleration, respectively.

The symbols used in the accompanying sketch and mathematical analysis are as follows:

R = crankpin radius
L = connecting-rod length
θ = angle of displacement with respect to the horizontal
h = offset distance of the slider with respect to the crank
l = Minimum distance of the slider with respect to the crank measured along the horizontal.



$$L^2 = (h + R\sin\theta)^2 + (l + X - R\cos\theta)^2$$

$$X^2 + (2l - 2R\cos\theta)X + 2hR\sin\theta - 2lR\cos\theta - K = 0$$

where $K = L^2 - h^2 - l^2 - R^2$

$$X = R\cos\theta - l + \sqrt{R^2\cos^2\theta - 2hR\sin\theta + K + l^2}$$

$$V_x = \frac{dx}{dt} = \left(-R\sin\theta - \frac{2R^2\cos\theta\sin\theta - hR\sin\theta}{2\sqrt{R^2\cos^2\theta - 2hR\sin\theta + K + l^2}}\right)\frac{d\theta}{dt}$$

$$A_x = \frac{d^2x}{dt^2} = \left(-R\sin\theta - \frac{2R^2\cos\theta\sin\theta - hR\sin\theta}{2\sqrt{R^2\cos^2\theta - 2hR\sin\theta + K + l^2}}\right)\frac{d^2\theta}{dt^2}$$
$$+ \left(\frac{d\theta}{dt}\right)^2\left(R\cos\theta + \frac{(R^2\cos\theta\sin\theta + hR\cos\theta)^2}{(R^2\cos^2\theta - 2hR\sin\theta + K + l^2)^{\frac{3}{2}}}\right)$$
$$- \left(\frac{d\theta}{dt}\right)^2\left(\frac{2R^2\sin\theta - 2R^2\cos^2\theta - hR\cos\theta}{2\sqrt{R^2\cos^2\theta - 2hR\sin\theta + K + l^2}}\right)$$

Sketch and mathematical analysis of the offset slider-crank mechanism

This paper was prepared expressly for AGRICULTURAL ENGINEERING, and is taken from the author's graduate thesis, entitled "Analysis of the Combine for the Direct Harvesting of Navy Beans."

The author: ANDREW J. ASHER, graduate student in agricultural engineering, Michigan State College, East Lansing.

AUTHOR'S NOTE: In following through the mechanics of solution according to the accompanying mathematical analysis, a consistent system of units should be used to get answers in the same units as desired.

Evaluation of Air Resistance to Freely Falling Drops of Water

By Robert L. Green
MEMBER ASAE

IN 1941 Laws(2)* published data on the terminal velocities of water drops from 1.7 to 5.04 mm in diameter after they had fallen various distances from 0.5 to 20.0 meters. The drop diameters were determined on the basis of the equivalent spherical radii of known masses of water, even though Laws recognized this to be an approximation since he included a drop photograph by Edgerton in the report. The photograph showed the actual shape of a drop to be that of an oblate spheroid with the bottom of the drop flattened by the resistance of the air. More recent work by Blanchard(1) substantiates this and further shows that a drop oscillates from slight oblation to extreme oblation as it falls. This oscillation, caused by the external force of air resistance and the internal force of surface tension, allows drops larger than 5.4 mm equivalent diameter to be broken into two or more parts by the resistance of turbulent air while the surface tension of drops 4.6 mm equivalent diameter and smaller is effective in producing stable drops. In the range between these diameters the drops may or may not separate.

Since the drop shape varies, the sectional area perpendicular to its path, on which the air resistance has its principal effect, also varies. It follows then that for drops larger than 5.2 mm there is no terminal velocity because if the distance of fall is sufficient the drops will break into smaller drops. It is obvious also that the effect of air resistance on a falling drop varies, reaching a maximum with extreme oblation and a minimum when the horizontal drop axis is a minimum. From this analysis it becomes apparent that for stable drops there is no true terminal velocity but a mean terminal velocity that is approached only as the horizontal drop axis approaches a maximum and is exceeded when the oblation is a minimum.

Mathematical analysis of the data presented by Laws, however, does yield values for the resistance of air to the falling drops of water, if the mean terminal velocity discussed above is considered as the terminal velocity. The velocities measured by Laws are, from the physicist's viewpoint, relatively low, justifying the assumption that the resistance varies with the first power of the velocity. Since the forces involved are gravity and air resistance, the total force, $F = mg - KV$, when m = mass, g = force of gravity, K = air resistance, and V = velocity of the falling drop. Newton's second law of motion may be written and K evaluated as follows:

$$m\,(dv/dt) = mg - KV \qquad [1]$$

$$\frac{dv}{dt} + \frac{KV}{m} = g$$

$$Ve^{(K/m)t} = \int ge^{(K/m)t}\,dt$$

$$\frac{K}{m}ge^{(K/m)t} + C$$

$$V = \frac{K}{m}g + Ce^{-(K/m)t}$$

At time $t = \infty$, t = terminal velocity, and $Ce^{-(K/m)t} = 0$

then $$V_t = \frac{K}{m}g \text{ and } K = \frac{V_t\,m}{g} \qquad [2]$$

From Laws' data for a 1.17 mm drop V_t = 460 cm per sec and the mass of a 1.17 mm drop is 0.00084 g using specific gravity as 1.0, then

$$K = \frac{460\,(0.00084)}{980} = 0.000394$$

Similar calculations for other values of m and V_t from columns 1 to 4 of Table 1 yield the results shown in column 5. From equation [2], since V_t and g are both constants, K is shown to be a function of mass and therefore a function of drop diameter. By plotting values for K versus diameter on logarithmic scales, the relationship is determined to be $K = .000251d^{3.52}$, when d = the equivalent spherical diameter.

TABLE 1

Drop diameter in mm	Minimum fall distance to attain V_t in meters	V_t, cm sec	M, g	K, g
1.17	2.2+	460	0.00084	0.000394
2.32	5.0+	666	0.00654	0.00440
2.34	5.0+	705	0.00663	0.00477
3.00	7.2	805	0.01412	0.01157
3.92	7.8−	885	0.02734	0.02465

NOTE: The first, second, and third columns of this table are based on Laws' data.

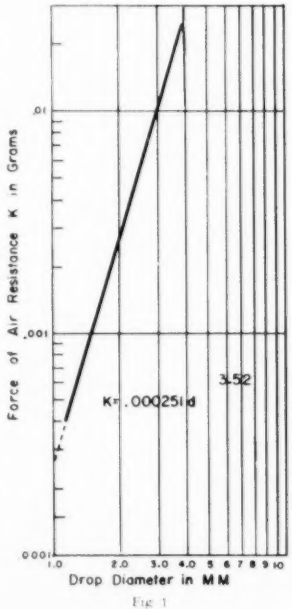


Fig. 1

As shown in Fig. 1 the points very closely approach the desired straight line. The variation that is present may be due to experimental error but is more likely the result of velocity measurements when the oscillation caused the velocity to vary from the mean terminal velocity of the drops measured.

This evaluation of K has been made in the theoretical analysis of the dynamics of irrigation sprinklers and is presented here for the information and criticism of those concerned with the effects of water drops, either from rainfall or from irrigation sprinklers on the soil.

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This paper was prepared expressly for AGRICULTURAL ENGINEERING, and is authorized for publication as Journal Paper 1260 of the Michigan Agricultural Experiment Station, East Lansing, Project 132. It reports on a portion of an investigation on the mechanics of sprinkler irrigation and the effects of sprinkler irrigation on the soil.

The author: ROBERT L. GREEN, assistant professor of agricultural engineering (on leave), Louisiana State University (Baton Rouge).

*Numbers in parentheses refer to the appended references.

1951 Kansas Flood Area

LOSSES caused by the disastrous flooding in Kansas during July, 1951, are estimated at more than a billion dollars. Fully 40 per cent of these losses occurred on the upland along the flood plains of the tributary streams where presently authorized flood control programs would afford no protection. These statements are contained in a report of an investigation of the Kansas flood area recently issued by the U. S. Soil Conservation Service.—*Journal of Soil and Water Conservation.*

A Basic Concept of Equilibrium Moisture

By S. M. Henderson
MEMBER ASAE

EQUILIBRIUM moisture content of hygroscopic materials, which include all farm products, is important to agricultural engineers because of its direct relationship to storage and drying problems. The moisture content of a stored farm product approaches a value controlled by the ambient relative humidity and temperature. The value approached by a drying product is determined by the relative humidity and temperature of the drying air. These moisture contents of approach, which are known as "equilibrium" moisture contents, are the subject of this paper.

The water in a hygroscopic material of a certain moisture content produces a water vapor pressure, p, which is less than the saturated water vapor pressure of pure water, p_s, at the same temperature as the material. The ratio of these pressures, p/p_s, is the equilibrium relative humidity for that particular moisture content and the temperature of the material. The equilibrium moisture curve is a graphic expression of the relationship between the moisture content of a material and its equilibrium relative humidity. Temperature affects the curve somewhat, an increase in temperature causing a slight reduction in moisture content for a fixed relative humidity.

This study was made to determine the mathematical characteristics of equilibrium moisture curves, special consideration being given the relationship of temperature to the position of the curves. It was prompted by the need for *(a)* a method for extrapolating limited data to other relative humidities and moisture contents, *(b)* a process for evaluating the shift of the curve due to temperature changes, *(c)* simplified techniques for observing the curve, *(d)* a reliable procedure for estimating heats of wetting or latent heats, and *(e)* refinement of the drying process calculations.

Methods of Observation. Most equilibrium moisture data have been secured by placing a small sample of the material in a sealed container with a sulfuric acid solution of a specific concentration that produces a certain specific water vapor pressure or relative humidity. A change of moisture content causes the sample to adjust its equilibrium relative humidity to the relative humidity produced by the solution. The moisture content of the material is then determined by an accepted method and a point on the curve established. A series of observations at different acid concentrations provides a complete equilibrium moisture curve.

Three difficulties experienced with this procedure must be recognized: *(a)* If the air in the container is not stirred, long periods may be required to reach equilibrium. Consequently, samples may be removed from test before reaching an equilibrium condition. *(b)* Because of the long test period sometimes required, samples exposed at approximately 85 per cent relative humidity or higher may mold before the endpoint is reached. The moisture of respiration of the mold will give a false high equilibrium moisture content. *(c)* Most of the data observed by this method are based on sulfuric acid vapor pressures published by Wilson in 1921 (25)*. Later comparable data by Greenewalt(11) show less temperature effect on the vapor pressure at a specific acid concentration than those of Wilson†. Any temperature curves based upon Wilson's data would consequently be questionable.

Wilson and Fuwa (26) observed equilibrium moisture relationships by bubbling air through absorption towers containing saturated salt solutions. The exhaust air from the towers, whose relative humidity depended upon the salt used, was passed through a small sample of the material under study. Its moisture content changed so that its vapor pressure became the same as that of the air.

This method is much faster than the procedure discussed earlier and eliminates objections *(a)* and *(b)* previously noted. However, it does not permit observation of the temperature effect since temperature data for many of the salts used are meager.

Although direct measurement of vapor pressures by a method described by Legault, Makower, and Talburt (14) is scientifically exact and readings can be made in an hour or less, special equipment and exceptional skill are required if unquestionable results are to be expected.

Brockington, Dorin, and Howerton (5) used an electric hygrometer to measure ambient relative humidity of the air in a sealed container. This device eliminates some of the objections to the other systems, such as skill required, cost of equipment, and time required (approximately 2 hr). However, studies with a comparable piece of equipment did not yield satisfactory curves at temperatures below 80 F, apparently because of inadequate temperature correction data.

Wet- and dry-bulb readings of the air surrounding a confined sample, as described by Hukill (12), is a fast and scientifically correct procedure, but ambient conditions must be maintained within very small tolerances and the readings must be made with greater than conventional accuracy.

Each of these procedures has certain advantages, but none has proved satisfactory in every respect.

The Equation. The water contained in a hygroscopic material is bound within the material in some chemical or physical manner or in a combination of these. It is an intimate part of the material but does not materially change the physical or chemical properties. Evidence indicates that the predominant fixing mechanism is adsorption. The molecules of the material attract and physically hold the water molecules. Thus the binding is assumed to be a surface phenomenon, although moisture of solution, hydration, and chemical combination may also be present in limited amounts.

The equilibrium moisture content curves for a number of materials were found to have the following mathematical characteristic:

$$1 - rh = e^{-k'M^n} \quad [1]$$

in which rh = equilibrium relative humidity, expressed as a decimal for convenience
M = equilibrium moisture content, dry basis, per cent
k' = factor, varying with material
n = exponent, varying with material.

The equilibrium moisture curves for 18 sets of data are shown in Figs. 1 to 7. The published data, shown by the open points, were plotted in the conventional manner and curves smoothed through them. Two apparently reliable points on the curve, usually at approximately 20 and 75 per cent equilibrium relative humidity, were selected for computing values of k' and n. These values were then used for calculating additional points (shown closed), which were added to the curves. The remarkable coincidence of the observed and calculated points is an indication of the appliability of equation [1]. The deviations of the plotted curves for shelled corn, flaxseed (Fig. 3) and dried prunes (Fig. 6) may be due to errors in observing the original data, such as those discussed previously. A better fit may have been possible with flaxseed and soybeans (Fig. 2) for values calculated on the basis of the oil-free dry matter. The results were not explicit enough, however, to report graphically.

The Temperature Effect. In 1906, Gibbs (20) proposed

This paper was presented at the annual meeting of the American Society of Agricultural Engineers at Houston, Tex., June, 1951, as a contribution of Farm Structures Division.

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*Numbers in parentheses refer to the appended references.

†Other sources for these data are International Critical Tables and Chemical Engineer's Handbook (Perry) 3rd edition, 1950.

the following thermodynamic relationship as a basis for adsorption

$$\frac{\partial \sigma}{\partial s} = \left(\frac{\partial P}{\partial v}\right)_T \quad [2]$$

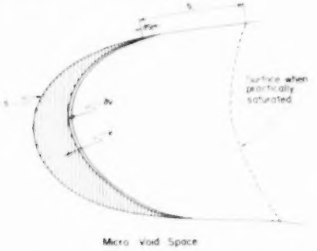
σ = surface tension of the adsorbed liquid, solid to liquid interface, pounds per foot or foot-pounds per square foot

v = liquid volume, cubic foot

s = wetted solid surface, square feet

P = osmotic pressure, adsorbed liquid to vapor interface, pound per square foot.

This proposal presumes that the quantity of water, v, is a function of the surface, s, upon which it is adsorbed. Thus the water might be arranged in a pattern such as shown in the accompanying sketch of microvoid space, an arrangement presuming multimolecular adsorption‡.



‡Two concepts of adsorbed molecular arrangement have been advanced (6). Unimolecular adsorption assumes an adsorbed layer one molecule thick, multimolecular more than one molecule thick. Neither has been substantiated.

The osmotic pressure, P, can be defined thus (17)

$$P = \frac{RT}{v_l} ln \frac{p_s}{p} \quad [3]$$

RT = gas content and absolute temperature, R degree

v_l = a mole liquid volume, cubic foot per mole weight

p_s = saturated vapor pressure of the liquid at T

p = vapor pressure of adsorbed liquid.

Partial differentiation of equation [3] of P relative to p gives

$$\partial P = \frac{RT}{v_l} \partial ln\, p \quad [4]$$

Let C be the concentration of adsorbed liquid in moles per square foot of wetted surface so that

$$\frac{\partial v}{\partial s} = v_l C \quad [5]$$

Formulas [2], [4], and [5] combined then yield

$$\partial \sigma = CRT\, \partial ln\, p \quad [6]$$

which integrates to

$$\sigma_s - \sigma = CRT\, ln \frac{p_s}{p} \quad [7]$$

This expression was originally derived by Bangham (3, 4) in his discussion of the adsorption of vapor on charcoal. It relates the concentration of adsorbed vapor, C, the temperature, T, the equilibrium relative humidity, p/p_s, and the energy required per square foot where surface is exposed by removal of moisture. The pressure, p_s, is the saturated pressure of water at temperature T.

Equation [7] defines conditions for unwetted areas such as

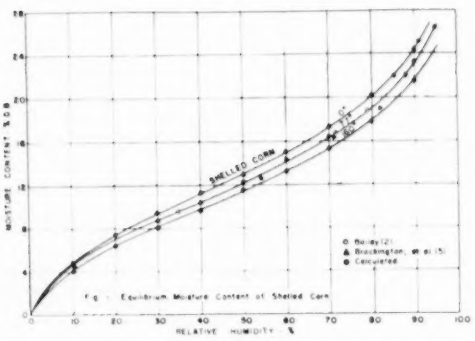


Fig. 1. Equilibrium Moisture Content of Shelled Corn

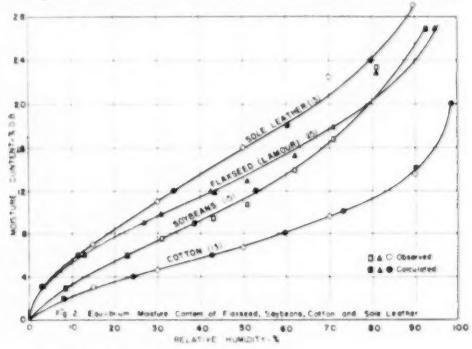


Fig. 2. Equilibrium Moisture Content of Flaxseed, Soybeans, Cotton and Sole Leather

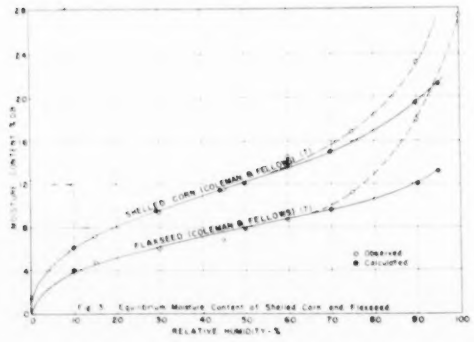


Fig. 3. Equilibrium Moisture Content of Shelled Corn and Flaxseed

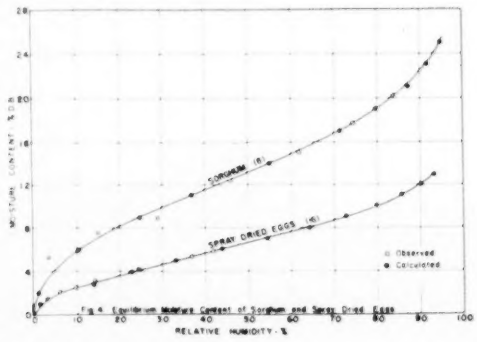


Fig. 4. Equilibrium Moisture Content of Sorghum and Spray Dried Eggs

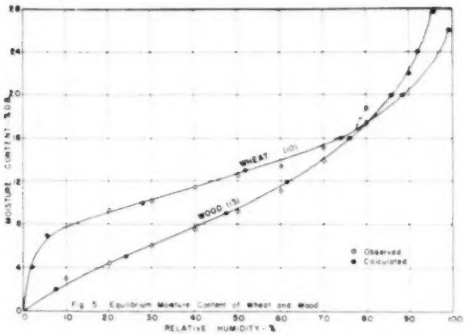


Fig. 5. Equilibrium Moisture Content of Wheat and Wood

shown by ϵ_f, in the accompanying micro sketch. It defines the factor relationship when the exposed surface is varied or for various extents of exposed surface. Since our interest is with the moisture which is present and the accompanying pressures and energies, integration of equation [6] between σ and σ_o is advisable. This can be done by substituting $p - p_s$ for p in equation [6] and integrating between limits σ and σ_o. This substitution recognizes the presence of water rather than its absence as a reference and shifts the operating curve $-p_s$ on the abscissa without changing the ordinate values. Integration yields the energy required for a change in the covered surface in terms of p_s and p and is

$$\sigma - \sigma_o = CRT \ln \frac{p - p_s}{-p_s}$$

This can be written as

$$-\ln \frac{p_s - p}{p_s} = \frac{CRT}{\sigma - \sigma_o} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad [8]$$

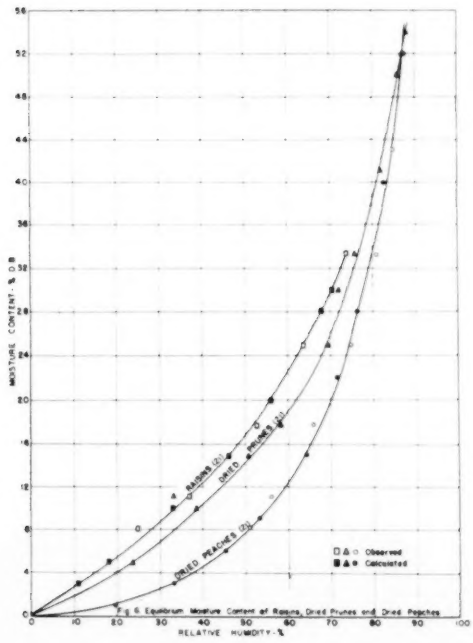


Fig. 6. Equilibrium Moisture Content of Raisins, Dried Prunes and Dried Peaches

Since C is the quantity of adsorbed moisture per unit of wetted area and M the quantity per total wetted area, the following relationship may be assumed

$$C = k_1 M^a \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad [9]\S$$

Furthermore, since the change in surface energy, $\partial\sigma$, is directly related to the change in quantity of adsorbed moisture, ∂x, equation [2], these factors are assumed to be related thus:

$$K_2 \frac{1}{\sigma_o - \sigma} = \epsilon_f / x = k_2 M^b \quad . \quad . \quad . \quad . \quad . \quad [10]\S$$

Therefore, by substituting equations [9] and [10] in [8], and R, k_1, and k_2 being combined in k, equation [11] results in

$$-\ln \frac{p_s - p}{p_s} = kTM^n$$

or

$$1 - \frac{p}{p_s} = \epsilon^{-kTM^n} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad [11]$$

This expression is identical to the observed relationship, equation [1], since $p/p_s = rh$, except that a temperature factor has been added by a thermodynamic process. The value of p_s is the saturated pressure of water vapor at temperature T. Values of the constants k and n for the 17 curves shown in Figs. 1 to 7 were calculated and are reported in Table 1.

TABLE 1. VALUES OF CONSTANTS, k AND n, FOR VARIOUS MATERIALS

Material	Constants		Temperature of observation, F°	Reference
	k	n		
Shelled corn	1.10×10^{-5}	1.90	77	2, 5
Shelled corn	1.59×10^{-6}	2.68	77.83	7
Wheat	5.59×10^{-7}	3.03	90	10
Sorghum	3.40×10^{-6}	2.81	70	8
Soybeans	3.20×10^{-5}	1.52	77	15
Flaxseed	4.00×10^{-6}	2.81	77.83	7
Flaxseed	6.89×10^{-6}	2.02	77	15
Raisins	7.13×10^{-3}	1.02	75	21
Dried peaches	4.11×10^{-4}	0.564	75	21
Dried prunes	1.25×10^{-4}	0.865	75	21
Cotton	4.91×10^{-5}	1.70	77	15
Sole leather	6.70×10^{-6}	1.92	77	15
Wood	5.34×10^{-5}	1.41	77	15
Spray dried eggs	2.95×10^{-5}	2.00	86	16
Colloidal soil	2.28×10^{-6}	2.30	77	1
Natural clay	7.53×10^{-5}	1.72	77*	24
Oven dried clay	2.52×10^{-4}	1.93	77	24

*Assumed.

§Note that there is no indication of the magnitude or sign of the exponents a and b or the constants k. They could be equal, negative, or positive, equal to, greater or less than one.

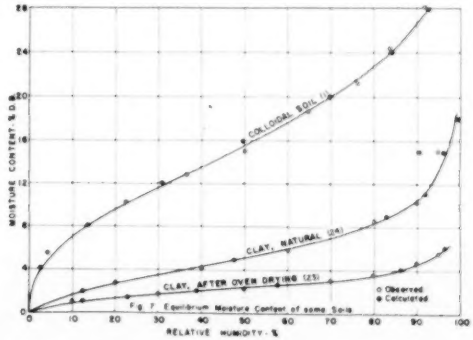
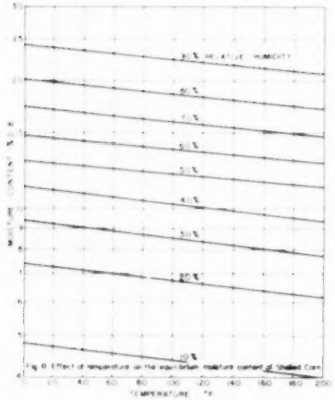


Fig. 7. Equilibrium Moisture Content of some Soils



The effect of temperature upon the equilibrium relative humidity properties of a material can be found by converting equation [11] to

$$\frac{\ln(1-rh)}{kT} = M^n \quad \ldots \quad [12]$$

holding relative humidity constant and determining the relationship between temperature and moisture content. Results of such a procedure for a number of relative humidities are shown in Fig. 8 for shelled corn. The zero and 100-deg curves of Fig. 1 were plotted from points taken from Fig. 8.

DISCUSSION

An empirical equation, [1], found to represent conventional equilibrium moisture data was established rigorously by a thermodynamic procedure — the derived equation, [11], including the effect of temperature upon the equilibrium relative humidity — moisture content relationship.

The equation will make it possible *(a)* to extrapolate limited data to other relative humidities and moisture content, *(b)* to determine the temperature effect upon the relative values, *(c)* to provide a complete curve with fewer observations, two being the minimum, and *(d)* to report or record equilibrium moisture data by values of k and n, such as in Table 1. Calculation of latent heats of adsorption by a procedure established by Othmer and Sawyer (18, 19), discussed by Gallaher (9), was investigated. Although explicit numerical results are possible, further study appears advisable because of some inconsistencies between calculated and observed values.

The equilibrium moisture content of a material changes as it dries. The equation can probably be used in the calculation of drying times. Additional study of these applications is intended.

The author recognizes that equations [9] and [10], which are used in the derivation are assumed and that Gibb's adsorption theory [2], has never been completely substantiated. Furthermore, since the temperature feature of the formula is related to the assumed moisture relationships noted above, experimental confirmation of its validity is advisable before urging its general use. Nevertheless, the formula appears generally acceptable for the following reasons:

1. The derivation is thermodynamically rigorous.

2. The observed and calculated points are remarkably coincident.

3. The calculated curve shift due to temperature is in the same direction and general magnitude as the available limited observations.

4. The formula satisfies the following recognized characteristics of equilibrium moisture curves:

(a) The equilibrium relative humidity is zero at zero moisture content.

(b) The equilibrium relative humidity approaches 100 per cent as the moisture content becomes infinite.

(c) The curve slope approaches infinity as the moisture content approaches zero or infinity.

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NEWS SECTION

Nominations for 1952-53 ASAE Officers

THE Nominating Committee of the American Society of Agricultural Engineers—A. W. Farrall (chairman), T. E. Hienton, and W. W. Weir—has placed in nomination the following members of the Society for the various elective offices to be filled at the next annual election of officers which will be conducted by letter ballot in February:

NOMINEE FOR PRESIDENT

IVAN D. WOOD is a native of Nebraska, and one of the early graduates of the pioneer professional agricultural engineering curriculum at the University of Nebraska. He received his bachelor's degree there in 1912, and his master's degree in 1913. From 1910 to 1913 he was a student assistant in the agricultural engineering department. On receiving his master's degree he took a summer surveying job as instrument

IVAN D. WOOD

man and chief of party with the John L. Roper Lumber Co. of Norfolk, Va.

In September he returned to his alma mater as instructor in land reclamation. With a school year of teaching experience as a background, he was transferred to extension work in July, 1914, as extension engineer specializing in irrigation and reclamation subjects. This started him in the career which has earned him the unofficial title of dean of extension agricultural engineers.

World War I interrupted Mr. Wood's extension activities for a year in 1918-19 while in training in the fledgling U.S. Army Air Service.

Back in Nebraska in 1919, drainage and farm buildings were added to his extension responsibilities. In the same year he became a member of the American Society of Agricultural Engineers. He continued in this work until 1940, with an interruption of a few months in 1934-35 to serve as state director of emergency conservation camps in Nebraska, and again in 1935-36 as chief of engineering for the Shelterbelt Project in 6 states.

Federal work claimed him in 1940 for double duty as district engineer in the Farm Security Administration with a district area of 7 states, and area engineer for the 17 western states in the USDA Water Conservation and Utilization Program.

Since July, 1945, he has been irrigation engineer in the research division of the U.S. Soil Conservation Service. In this position his responsibilities include interpretation of research data for field use; cooperation between the SCS and various other agencies in conducting interagency training schools on irrigation subjects; and training of extension agricultural engineers and personnel in various branches of the Soil Conservation Service.

Recognized leadership in extension activities and in his technical field has resulted in his appointment to serve, for various periods, as chairman or member of various state and University of Nebraska committees. These have included committees on extension exhibits, rural electrification, SCS research, land-use planning, and commemoration of the signing of the Smith-Lever Bill for extension work. He has also served on the Nebraska State Advisory Council, the Water Resources and the Agricultural Advisory Committees of the State Planning Board, and the Agricultural Committee of the Lincoln, Nebraska, Chamber of Commerce.

(Continued on page 34)

ASAE Meetings Calendar

January 18—IOWA ILLINOIS SECTION, Short Hills Country Club, East Moline, Ill.

January 29—MINNESOTA SECTION, University of Minnesota, University Farm, St. Paul.

January 31—PACIFIC COAST SECTION, Hunt Hall, University of California, Davis, Calif.

February 4-6—SOUTHEAST SECTION, Atlanta Biltmore Hotel, Atlanta, Ga.

February 8—WASHINGTON (D.C.) SECTION, Room 6962, South Bldg., USDA, Washington.

February 16—MICHIGAN SECTION, Dearborn Motors Corp., Birmingham, Mich.

March 21—OHIO SECTION, Ives Hall, Ohio State University, Columbus.

April 10 and 11—PENNSYLVANIA SECTION, Agricultural Engineering Bldg., Pennsylvania State College, State College.

June 16-18—45TH ANNUAL MEETING, Hotel Muehlebach, Kansas City, Mo.

NOTE: Information on the above meetings, including copies of programs, etc., will be sent on request to ASAE, St. Joseph, Michigan.

NOMINEES FOR VICE-PRESIDENT

L. H. SKROMME

E. W. TANQUARY

NOMINEES FOR COUNCILOR

D. E. WIANT

H. N. STAPLETON

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Nominations for 1952-53 ASAE Officers

(Continued from page 33)

From the earliest years of his membership in ASAE he has been one of its most consistently active members. He has served twice, in 1929-30 and 1946-47, as chairman of the Soil and Water Division, formerly known as the Reclamation Division. He has also served as member and chairman of its erosion committee and chairman of its committee on power costs for irrigation pumping.

In the farm structure field he has served as a member of the Committee on Dairy Construction and Equipment, Committee on Cooperative Building Plan Service, Committee on Farm Structures Economics, and Committee on Farm Building Design.

On the standing committees of the Society as a whole, he has been chairman of the Extension Committee and a member of the Meetings Committee and the Paper Awards Committee.

Among members who have seen him in action at ASAE or other meetings, he may be even better known as a clear, able, and interesting speaker, an alert chairman always in full command of any meeting over which he presides, and a solid, practical engineer with the extension man's liking for people developed to a high degree.

NOMINEES FOR VICE-PRESIDENT

LAWRENCE H. SKROMME grew up on a tall-corn farm in Iowa. His early interest in farm progress developed with membership in 4-H Clubs and the FFA. In the latter he was winner of a state farmer award. At Iowa State College he graduated in agricultural engineering with honors in 1937. He was elected to Alpha Zeta, Tau Beta Pi, Phi Kappa Phi, and in his senior year was president of the ASAE National Council of Student Branches.

From college he went to the Goodyear Tire and Rubber Co., where he worked as draftsman, designer and test engineer on farm tractor and implement tires.

In 1941 he moved to Detroit as project engineer with Harry Ferguson, Inc., and earned subsequent advancement to assistant chief engineer.

Last spring he was selected for his present position as chief engineer of the New Holland Machine Division of The Sperry Corp.

As a member of ASAE since 1937 he has been particularly interested in the Power and Machinery Division and is currently a member of its Steering Committee. He has served on the Committee on Student Branches, and as its chairman for 1940-41. He has also served on the Committee on Technical Paper Awards, being its chairman last year.

In related activities he is a member of the American Society for Engineering Education and of the Engineering Advisory Committee of the Farm Equipment Institute.

• • •

EDWIN W. TANQUARY became an agricultural engineer via the farm equipment pattern shop and foundry route.

A native of Canton, Illinois, he studied mechanical drawing in high school just in time to qualify for service in the Corps of Engineers, U.S. Army, in 1918. After a period of non-commissioned service he earned a commission as a first lieutenant and served through parts of 1919 and 1920 as an instructor in small arms.

Returning to his home town after military service, he went to work in the pattern shop at the Canton, Ill., plant of the International Harvester Co. After studying foundry engineering by correspondence and completing a student course in the foundry, he was promoted in 1922 to assistant foreman in the grey iron and malleable foundry. In another two years he returned to the pattern shop as assistant foreman. He graduated into the engineering department in 1928 to work on tillage equipment, and served there in increasingly responsible capacities until 1938.

Next he was moved to the Chicago headquarters of the Company as engineering specialist, to work on special assignments, field complaints, tillage implements, hydraulic systems, and related matters.

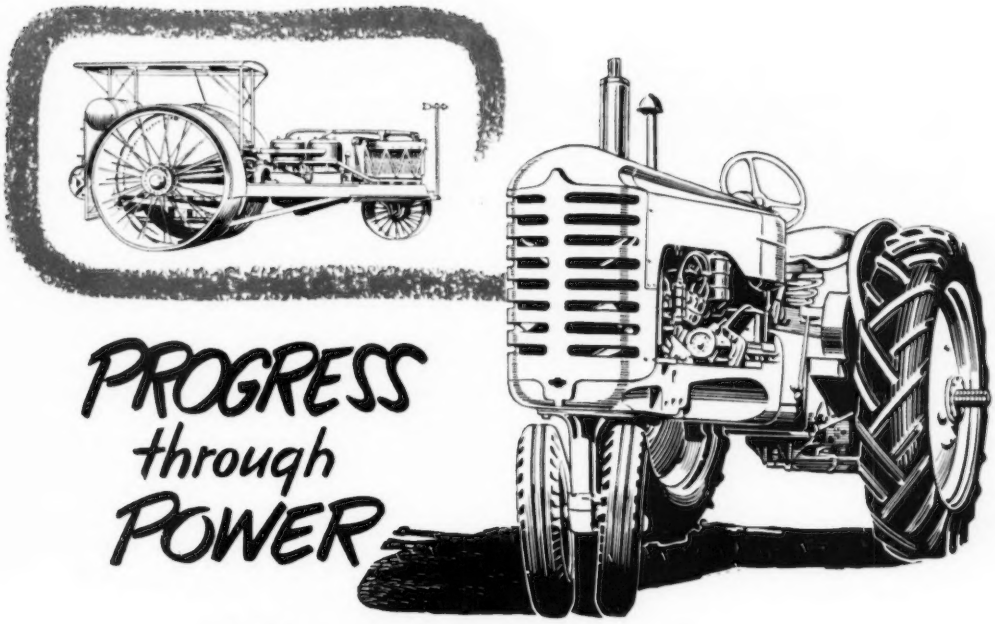
Since 1945 he has been special engineer in the Chicago headquarters, responsible for coordinating the work of the implement and farm tractor engineering departments. He was also named to represent the Company on farm implement engineering in the Engineering Advisory Committee of the Farm Equipment Institute. His work as a member of that Committee resulted in his subsequent selection as its chairman, a position he has held since 1945.

Elected to membership in the Society in 1946, he contributed to the development and revision of ASAE Bulletin No. 44, entitled "Farm Tractors Built or Convertible to ASAE Standard Dimensions", and to the Society's Standard, "Application of Hydraulic Remote Control to Farm Tractors and Trailing Type Farm Implements."

He served as vice-chairman of the Power and Machinery Division in 1949-50, succeeding to the chairmanship for the following year. He is a member of the Steering Committee of the Division. He is also a member of the technical board of the Society of Automotive Engineers.

NOMINEES FOR COUNCILOR

HERBERT N. STAPLETON, head of the agricultural engineering department at the University of Massachusetts, is a native of Kansas. He received his BS and MS degrees in agricultural engineering at Kansas State College in 1930 and 1931. (Continued on page 36)



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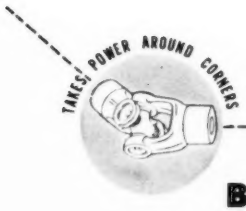

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FAIR WARNING

to spray equipment manufacturers

In addition to orders already booked for 1952 delivery, Oberdorfer will endeavor to produce for manufacturers of spraying equipment the quantities of pumps shown in the table below, which includes both our standard Series "52" and our new International Series I with carbon bearings.

As orders are received, the quantities available of each pump shown here will be reduced accordingly. The monthly production quota detailed below will be insufficient to meet the demand for Oberdorfer spraying pumps during the first half of 1952. If you expect to be shipped any Oberdorfer spraying pumps, be certain to place your order immediately.

SPRING 1952 SPRAYING PUMP PRODUCTION

Pump No.	Pipe Size	Jan.	Feb.	March	April	May	June
2AX or 2ZX	1/4"	500	500	500	500	250	250
3AX or 3ZX	3/8"	500	500	500	500	250	250
4AX or 4ZX	1/2"	2000	2000	2000	2000	1000	1000
7AX or 7ZX	3/4"	2000	2000	2000	2000	1000	1000
9AX or 9ZX	1"	2000	2000	2000	2000	1000	1000
2000	3/8"	250	250	250	250	125	125
3000	1/2"	250	250	250	250	125	125
4000	1/2"	500	500	500	500	250	250
7000	3/4"	1000	1000	1000	1000	500	500
9000	1"	1500	1500	1500	1500	750	750

Pump No.	Price	Pump No.	Price	Pump No.	Price
2AX —	$13.25	4ZX —	$22.00	2000 —	$15.75
2ZX —	17.50	7AX —	22.50	3000 —	20.00
3AX —	15.50	7ZX —	27.75	4000 —	22.25
3ZX —	20.50	9AX —	23.75	7000 —	28.50
4AX —	17.00	9ZX —	29.00	9000 —	29.75

Agricultural Pump Div., Oberdorfer Foundries, Inc.
1421 Thompson Rd., Syracuse, N. Y.

OBERDORFER

BRONZE SPRAYING PUMPS

Nominations for 1952-53 ASAE Officers

(Continued from page 34)

In September, 1931, he went to Pennsylvania State College as an instructor in the agricultural engineering department. His teaching was in basic courses on agricultural engineering, drainage, and farm power. In addition he assisted A. W. Clyde on current research projects.

His work in rural electrification, for which he became well known in the East, started in 1935 with an assignment as extension agricultural engineer at the University of Vermont. He had a large part in the development of a successful uniform plan for the extension of rural electric lines in the state.

By 1937 the University of Vermont was ready to serve as host to the annual New England Rural Electrification Institute, with a program developed around the economics of farm mechanization, with emphasis on the farm use of electric power.

Transferring to utility work in August, 1937, he was employed as agricultural engineer for the Green Mountain Power Corp. In this capacity he was directly responsible to the president of the Company for promotion of line extensions and load building. In a dairying state, he became one of the early leaders in developing electric dairy-stable ventilation and other sound applications of electric power to dairying.

By way of further identifying himself with the problems and progress of Vermont farmers, he purchased a small dairy farm in 1939. In its operation he became one of the early demonstrators of the possibilities in pasture irrigation and barn hay drying.

A call to military service in 1942 interrupted his activities in rural electrification for a 4-year period. He returned to his work with the Green Mountain Power Corp. in 1946 to help in the completion of its rural line building program.

He was selected in July, 1947, for a major responsibility in a program of development at the University of Massachusetts, to enlarge its service to the state in engineering education and research. Going there as research professor in agricultural engineering, he was named acting head of the agricultural engineering department in December, 1947, and head of the department in September, 1948. Under his direction the department has been expanded and now offers a professional curriculum under the administration of the college of engineering.

Since becoming a member of the Society in 1932, he has been particularly active in the College, Rural Electric, and Farm Structures Divisions and the North Atlantic Section. He was secretary of the latter from 1938 until he was called into military service in 1942.

• • •

DENNIS E. WIANT, professor of agricultural engineering, Michigan State College, took his first steps in higher education at Bloomsburg, Pa., State Teachers College. After graduating from that school he went to Iowa State College for his BS degree in agricultural engineering, and then to Kansas State College for an MS degree in agricultural engineering.

Thus prepared, in 1928 he became a member of the agricultural engineering staff at South Dakota State College. While there his primary technical field was farm power and machinery. For a short period in 1935, however, he also served as a farm representative in the Farmers Home Administration.

In 1939 he was called to Michigan State College to take charge of its teaching and research in rural electrification. From September, 1950, to the end of 1951 he was on sabbatical leave, collaborating with others in the preparation of a text on rural electrification. He is author and co-author of a number of bulletins on farm mechanical and electrical equipment, frozen foods and food freezing equipment, and hay processing.

Among related activities for rural electric progress, he is chairman of the Michigan Committee on Rural Electrification and a member of the Michigan Rural Communications Committee.

A member of ASAE since 1928, he has been active in various capacities in the Rural Electric and College Divisions and the Michigan Section. During the year of 1947-48 he served as vice-chairman of the Michigan Section during 1950-51 he was chairman of the Society's Rural Electric Division.

NOMINEES FOR NOMINATING COMMITTEE

HAROLD H. BEATY, rural service manager, Edison Electric Institute, New York, N. Y.

HOBART BERESFORD, head, agricultural engineering department, Iowa State College, Ames.

FRED R. JONES, head, agricultural engineering department, A. & M. College of Texas, College Station.

HOWARD F. MCCOLLY, professor of agricultural engineering, Michigan State College, East Lansing.

DAVID A. MILLIGAN, domestic sales manager, Harry Ferguson, Inc., Detroit, Mich.

FRANK J. ZINK, consulting engineer, Frank J. Zink Associates, Chicago, Ill.

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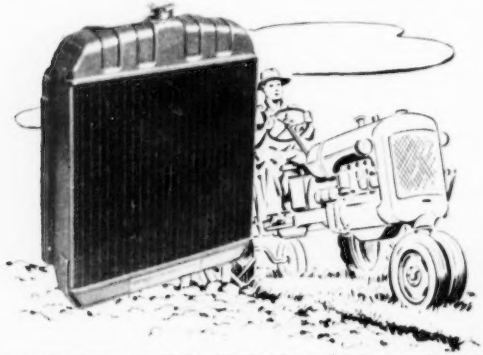

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Frank Lanham to Join ASAE Staff

THE Council of the American Society of Agricultural Engineers has appointed Frank Bristol Lanham, a member of ASAE since 1936, to the position of Assistant Secretary of the Society. The appointment was made at a regular meeting of the Council held during the ASAE Winter Meeting in Chicago last month.

Mr. Lanham is a native of West Virginia where he received his secondary school education. He matriculated in the agricultural engineering curriculum at Virginia Polytechnic Institute in 1931, receiving his bachelor of science degree in 1935. During the year following his graduation from VPI, he was enrolled as a research fellow in the agricultural engineering department at Iowa State College, and was awarded the master of science degree in agricultural engineering in June, 1936.

Frank B. Lanham (left) is congratulated by ASAE President Stanley Madill on the former's appointment as the new Assistant Secretary of ASAE

From 1936 to 1941, Mr. Lanham was employed as research agricultural engineer in the college of agriculture, University of Georgia, where in addition to his regular duties he edited several college bulletins including three annual reports of research and investigational activities of the institution. He is also a registered professional engineer (in both civil and agricultural engineering) of the State of Georgia.

Mr. Lanham is a veteran of World War II. He saw service with the U.S. Army from April, 1941, to December, 1945, three years of which was in the Southwest Pacific theater. He entered the service as a first lieutenant and was released with the rank of lieutenant colonel. During his service in the Southwest Pacific area, he received battlefield promotion from the rank of captain to major by direct citation of the Army commander, General Walter Kruger. Upon return to the United States, he was assigned to the assistant chief of staff, Army Ground Forces, Army War College, at Washington, with primary duty of congressional liaison and establishment of enlisted personnel policy. He also served three months as junior aide-de-camp to the late General Stilwell.

From January, 1946, to February, 1950, Mr. Lanham served successively as sales manager, credit manager, and general manager of the Bower Company, wholesale hardware jobbers located in Bainbridge, Ga.

Early in 1950, the urge to return to his first love, the profession of agricultural engineering, was too strong to be resisted, and Mr. Lanham severed his connection with the Bower Company to enroll as an industrial fellow in the agricultural engineering department at Iowa State College, where he is now pursuing graduate work leading to the degree of doctor of philosophy in agricultural engineering, the requirements for which he will complete this coming March. He will take up his new duties on the ASAE headquarters staff at St. Joseph, Michigan, some time during the spring months.

In college Mr. Lanham was a member of the social fraternity, Acacia, and was elected to three honor fraternities, Phi Kappa Phi, Alpha Zeta, and Gamma Sigma Delta. Outside of college organizations he has been especially active in the Methodist Episcopal Church, Boy Scouts of America, the Masons, and Rotary.

Besides his wife, Mr. Lanham has two daughters, Caroline and Kay, ten and five years of age, respectively.

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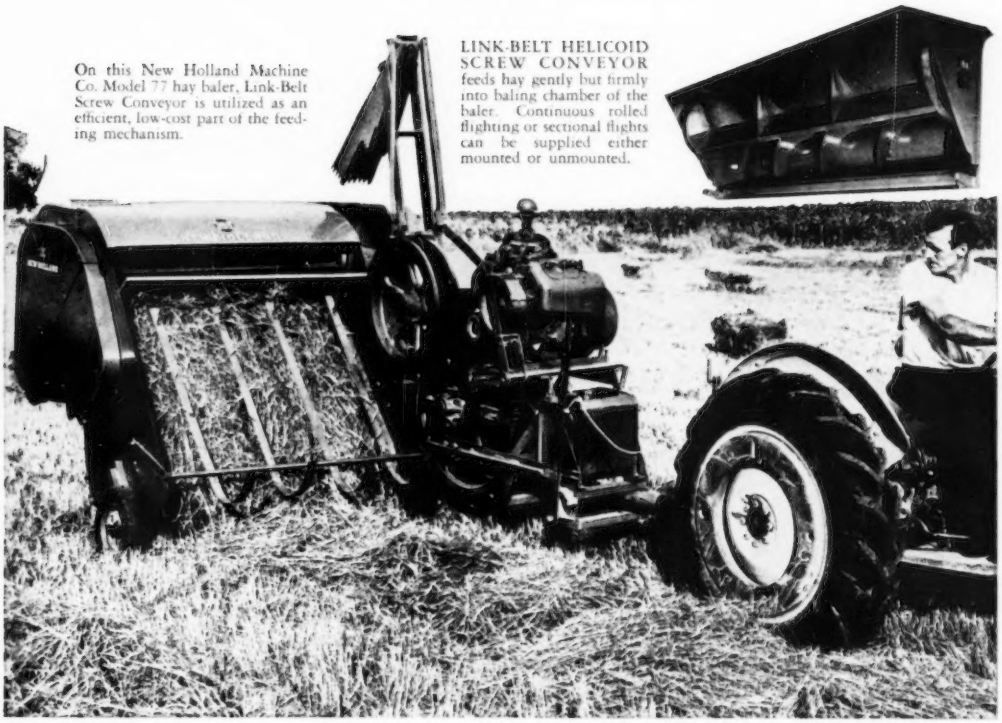

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The ASAE Winter Meeting

INTEREST in the Winter Meeting of the ASAE at Chicago, December 17-19, ran high as measured by registration, attendance at the various sessions, committee meetings, and comments.

Delayed trains and planes and otherwise bad travelling conditions resulted in a number of late arrivals, but the largest part of the attendance had been registered by the time the technical sessions opened at 9:30 Monday forenoon, December 17. By Wednesday afternoon a total of 965 had been registered. (It was erroneously reported during the meeting that the total registered attendance exceeded 1000.)

Evening sessions proved popular. Many of those present and not otherwise occupied on Monday evening took the opportunity to attend the illustrated talks by H. P. Smith, E. L. Barger, Roy Bainer and Parker Hess on their respective travels in Turkey, Guatemala, Japan, and Texas.

On Tuesday evening the Research Committee of the Farm Equipment Institute held its traditional dinner for college agricultural engineering department heads and research men. Speaking for industry on that occasion, H. B. Meeran, president of FEI, paid high tribute to the importance of agricultural engineering in the work of making improved equipment available to farmers.

A special trip to the remodeled offices and laboratories for the Portland Cement Association was well attended by farm structures men on Wednesday, December 19.

The Ingersoll Products Division, Borg-Warner Corp., held open house at its Chicago plant on Thursday for power and machinery engineers and others interested in seeing the manufacture of steel discs.

The Committee on Arrangements set up by the ASAE Chicago Section, and headed by C. I. Hamilton, chairman of the Section, provided registration and other services. Through overlapping membership in the Society's Committee on Public Relations, the Chicago Section also handled a large part of the service to the press, radio, and television news and feature services. Notably "at work" for the Society during the meeting, in addition to Mr. Hamilton, were Mr. and Mrs. Howard C. Rutt, Mr. and Mrs. John Wessman, Lee H. Ford, Fred A. Lyman, and Kenneth W. Snyder, representing the Chicago Section, and Chas. E. Ball and Arnold R. Daum representing the Society's Committee on Public Relations.

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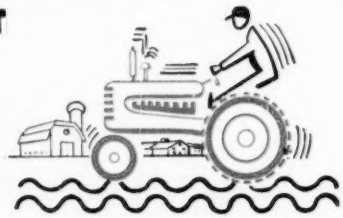
Violent Vibration



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Sugar Beet Technologists Meet in February

THE seventh general meeting of the American Society of Sugar Beet Technologists will be held at the Hotel Utah in Salt Lake City, February 5 to 8, 1952. The program for this meeting will include some 150 papers on general agronomy, genetics and variety improvement, entomology and plant pathology, agricultural engineering and chemistry, and factory operations.

The beet sugar industry has accomplished commendable advancement toward complete mechanization of its crop. In less than ten years, it has advanced from complete hand harvest to 80 to 85 per cent complete machine harvest. Some type of machine tool for weed control and stand reduction has been used on 40 per cent of the 1951 crop.

Agricultural engineers and others interested in the program are welcome to attend the meeting. For complete information on the program, accommodations, etc., write direct to James H. Fischer, secretary-treasurer, The American Society of Sugar Beet Technologists, P. O. Box 551, Fort Collins, Colo.

Agricultural Engineering Available in Microfilm Form

THE American Society of Agricultural Engineers has entered into an agreement with University Microfilms, Ann Arbor, Michigan, to make available to libraries its official journal, AGRICULTURAL ENGINEERING, in microfilm form.

One of the most pressing problems facing all types of libraries today is that of providing adequate space for a veritable flood of publications. Periodical publications pose an especially difficult problem because of their bulk and number.

Microfilm makes it possible to produce and distribute copies of periodical literature, in the form of an entire volume in a single roll, at a cost approximately equal to the cost of binding the same material in a conventional library binding.

Under the plan, the library keeps the printed issues unbound and circulates them in that form for from two to three years which corresponds to the period of greatest use. When the paper copies begin to wear out or are not called for frequently, they are disposed of and the microfilm is substituted.

Sales of the microfilm are restricted to those libraries subscribing to the paper edition, and the film copy is distributed only at the end of the volume year.

Under the arrangement for microfilming AGRICULTURAL ENGINEERING, the microfilm is in the form of a positive microfilm and is furnished on metal reels suitably labeled. Inquiries concerning their purchase should be directed to University Microfilms, 313 N. First St., Ann Arbor, Mich.

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Indelibly it attests Man's handling of a heritage . . . the discharge of a stewardship . . . the good and the bad . . . the successes and the failures.

Multi-colored are its pages . . . here, a line in the scarlet ink of anger . . . there, a word in the brilliant gold of kindness . . . passage after passage in the blue of despair and the silver of hope . . . in the green of petty prejudice and the purple of majestic tolerance.

And, fearing posterity's critics, he hesitates to leave it.

But then he remembers that this authorship of his is a commission, a charge that binds him to complete his share of the manuscript . . . and he knows that somewhere, somehow, he will find the courage and the inspiration.

So, once again, Man dips his pen . . . determined that this time he will author a better, a finer edition . . . and he reaches for a new book with pages which as yet are blank.

Carefully . . . with confident fingers . . . he inscribes the title:
Volume Nineteen Hundred and Fifty-Two.

JOHN DEERE • MOLINE • ILLINOIS

Applicants for Membership

The persons listed below have applied for admission to membership or for transfer of membership grade, in the American Society of Agricultural Engineers. Members of the Society who wish to comment or object to any of these applicants should write the Secretary of the Society at once. If there are no objections, and if confidential statements furnished by their references are satisfactory, these applicants will be voted on by the Council after February 15, 1952.

ALLISON, WILLIAM F.—Agr. engr., Soil Conservation Service, USDA, Victoria, Tex.

ANDERSON, LEE M.—Apprentice lineman, The Montana Power Co., Bozeman, Mont.

BEELMAN, HAINES L.—Student, Ontario Agricultural College, Guelph, Ont., Canada.

BENDER, WILBERT R.—Commercial engr., Virginia Electric & Power Co., Williamston, N.C.

BENZ, LEO C.—Student, North Dakota Agricultural College, Fargo, N.D.

BEYER, W. O.—Advisory capacity, McDowell Mfg. Co., Millvale, Pa.

BOBLE, LOUIS E.—In charge of res., Babson Bros. Co., Chicago, Ill.

BOURGEOIS, ALFRED L., JR.—804 Fort St., Plaquemine, La.

BOUSCAYROL, RENE—Administrator, Finca Tululu, Coyotenango, Guatemala, C.A.

BRADLEY, LELAND E.—Field rep., American Zinc Institute, Chicago, Ill.

BRUNS, EDWARD G.—Farm bldg. spec., agr. ext. serv., University of Wisconsin, Madison, Wis.

BULLARD, ARTHUR R.—Carpenter, R.R. 1, Mechanicsburg, Ohio.

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BUSSEY, CHARLES M.—Agr. engr., Soil Conservation Service, USDA, Victoria, Tex.

CAMPBELL, ARTHUR B.—Student, Ontario Agricultural College, Guelph, Ont., Canada.

CASH, DAVID L.—Pvt., U. S. Army (Mail) R.R. 2, Harvard, Ill.

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CLARK, CHARLES E.—Engr., United Co-op., Inc., Alliance, Ohio.

CLARK, JOHN D.—Design engr., The Oliver Corp., South Bend, Ind.

CLARK, JULIUS G., JR.—Farm mgr., Clark-land Farms, Lexington, Ky.

CLINE, AUSTIN R.—Jr. agr. engr., Shell Chemical Corp., San Francisco, Calif.

COLONY, FRANK A.—U. S. Army (Mail) R.R. 1, Iowa City, Iowa.

COOK, WENDELL C.—Farm rep., Central Vermont Public Service Corp., Rutland, Vt.

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DAUM, ARNOLD R.—Public relations spec., American Petroleum Institute, New York, N.Y.

DAVIES, GEORGE B.—Sales and engr., Lethbridge Iron Wks. Co., Ltd., Lethbridge, Alta., Canada.

DECKER, MARTIN, JR.—Instr. in agr. engr., Kansas State College, Manhattan, Kans.

DETRICK, ANDREW G.—Graduate student, Ohio State University, Columbus, Ohio.

DOERING, EUGENE J.—Plankinton, S.D.

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HAHN, CHARLES J.—Agr. engr., div. of water, Ohio Dept. of Natural Resources, Columbus, Ohio.

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HAMELSTROM, ALBERT W.—Agr. engr., Soil Conservation Service, USDA, Kadoka, S.D.

HANFORD, WILLIAM D.—Field engr., product eng. dept., McCormick Wks., International Harvester Co., Chicago, Ill.

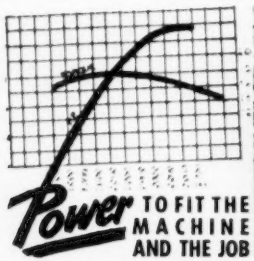
HANSEN, HUGH J.—Graduate student, Cornell University, Ithaca, N.Y.

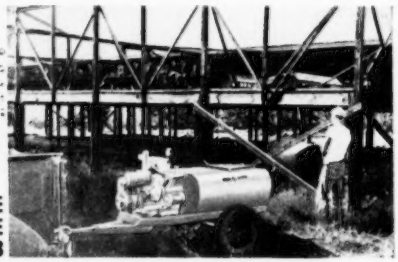
HANSEN, RALPH W.—Res. asst. in agr. eng., North Dakota Agricultural College, Fargo, N.D.

HANSON, RICHARD E.—Instr. in irrigation res., Kansas State College, Manhattan, Kans.

HARTMAN, WAYNE F.—Graduate student, University of Illinois, Urbana, Ill.

(Continued on page 44)





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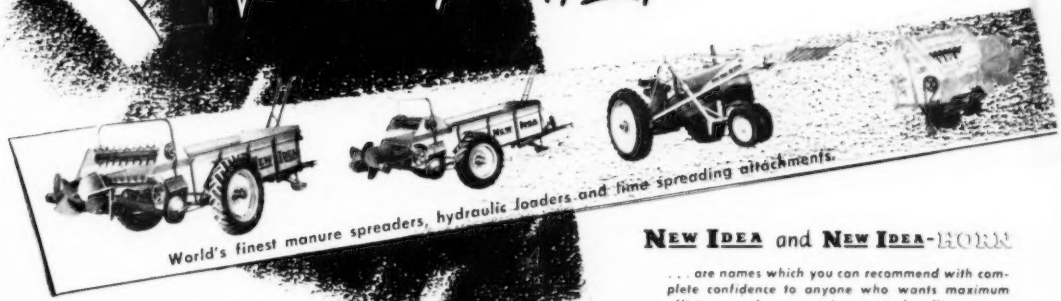

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HELLWIG, ROBERT E.—Agr. engr., The Belt Corp., Orient, Ohio.

HILBE, R. J.—Pres., Hilbe Eng., Inc., Glendora, Calif.

HOOK, DOUGLAS W.—Operator's helper, Tubular Service and Eng. Co., Odessa, Tex.

INOUYE, WILLIAM S.—Mechanical engr., San Francisco Naval Shipyards, San Francisco, Calif.

IRWIN, ROSS W.—Dist. supervisor of drainage, Ontario Agricultural College, Guelph, Ont., Canada.

JENNINGS, DANA C.—Adv. copywriter, Western Advertising Agency, Inc., Racine, Wis.

JONES, JOHN H.—Blockman, Allis-Chalmers Mfg. Co., Oklahoma City, Okla.

KELLEY, FENTON J.—Process engr., Allis-Chalmers Mfg. Co., Terre Haute, Ind.

KENDRICK, JUNIUS I.—Rural serv. engr., Alabama Power Co., Anniston, Ala.

KOCH, PAUL W.—Agr. engr., Soil Conservation Service, USDA, Bloomington, Ill.

KRAFT, HOWARD D.—Gas engr., Public Service Co. of No. Ill., Dixon, Ill.

KROUSE, EMILE S., JR.—Farm rep., Gulf States Utilities Co., Baton Rouge, La.

LANGSTON, LEWIS C.—Asst. ext. agr. engr., British Columbia Dept. of Agriculture, Vancouver, B.C., Canada.

LEIGH, BERTRAM J.—Asst. serv. mgr., Harris Mfg. Co., Stockton, Calif.

LEWIS, RICHARD I.—Asst. engr., Permco Mfg. Co., Peru, Nebr.

LYLE, LESTER D.—Farmer, Cunningham, Wash.

MAUST, JOHN E., JR.—Sr. draftsman, New Idea Div. of Avco Mfg. Corp., Coldwater, Ohio.

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MILBURN, WENDELL R., JR.—Agr. sales engr., The Ohio Power Co., Newark, Ohio.

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MILLER, JAMES B.—Production engr., Oregonia Bridge Co., Lebanon, Ohio.

MOJONNIER, HARRY G.—Milk cooler dev., Mojonnier Bros. Co., Chicago, Ill.

MORAN, KYLE I.—Agr. engr., Soil Conservation Service, USDA, Oskaloosa, Kans.

MORLAND, ROBERT B.—Agr. engr., Soil Conservation Service, USDA, Tillamook, Ore.

MORRIS, ROBERT J.—Student, Ontario Agricultural College, Guelph, Ont., Canada.

MURPHY, JAY J.—Field serv. engr., Caterpillar Tractor Co., Peoria, Ill.

NARVAEZ, RODOLFO—Asst. agr. engr., Servicio Tecnico Agricola de Nicaragua, Managua, D.N., Nicaragua, C.A.

NESTOR, ELLIS S.—Rural rep., Virginia Elec. & Power Co., Charlottesville, Va.

NORTH, MAX R.—Trainee, Massey-Harris Co., Racine, Wis.

OPPEL, FRED J., JR.—Graduate student, Oklahoma A. & M. College, Stillwater, Okla.

PARKER, THOMAS S.—Jr. agr. engr., Compania Frutera de Sevilla, Santa Marta, Colombia, S.A.

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PELTON, WILLIAM L.—Student, Ontario Agricultural College, Guelph, Ont., Canada.

POWELL, CHARLES D.—Engr., Doane Agricultural Service, Inc., St. Louis, Mo.

PRESANT, DONALD F.—Trainee, Goodison Industries, Ltd., Toronto, Ont., Canada.

PRUCNAL, CHESTER S.—Farmer, Hatfield, Mass.

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READY, JOHN F.—2nd Lt., U. S. Army. (Mail) 5406 York Circle, Warwick Gardens, Newport News, Va.

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ROSSITER, MYERS M.—U. S. Army Air Force. (Mail) Columbus Junction, Iowa.

ROWAN, JAMES D.—Graduate student, University of Georgia, Athens, Ga.

RYAN, THOMAS F.—Asst. field supt., agr. dept., Spreckels Sugar Co., Spreckels, Calif.

SHANKLIN, MILTON D.—Elec. adviser, Boone Elec. Co-op., Columbia, Mo.

SHEIDLER, CHARLES E.—Agr. engr., Soil Conservation Service, USDA, Mt. Vernon, Wash.

SHULL, HOLLIS—Graduate asst. in agr. eng., University of Nebraska, Lincoln, Nebr.

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(Continued on page 46)

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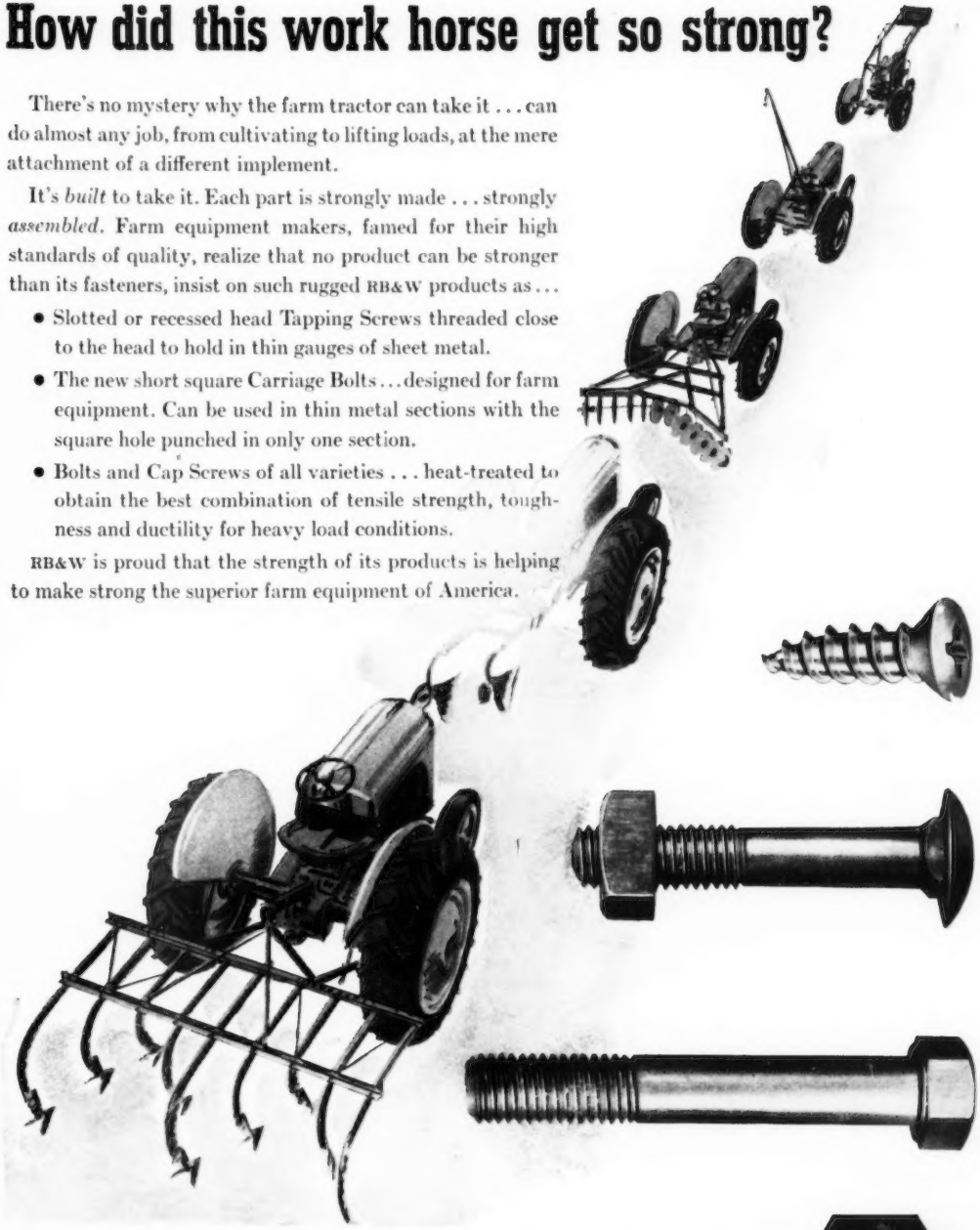

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(Continued from page 44)

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SMITH, J. E—Mgr., Mecklenburg Elec. Co-op., Chase City, Va.

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STAMM, ARTHUR G—Hydraulic engr., U. S. Bureau of Reclamation, USDI, Chico, Calif.

TAUBE, ROBERT O—Dynamometer operator, J. I. Case Co., Racine, Wis.

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THOMPSON, GENE T—County ext. agent, Ephrata, Wash.

THUERMAN, JOHN H—Asst. to chief engr., chain and transmission div., Chain Belt Co., Milwaukee, Wis.

TWIST, LAUREL G—Sales, Leach Co., Lake Geneva, Wis.

TYUS, LEWIS C—Farmer, R. R. 2, Cairo, Ga.

VAN NATTA, CHARLES R., JR—Farmer, Battle Ground, Ind.

WALSTROM, RUSSELL W—Chief engr., Sherman Products, Inc., Royal Oak, Mich.

WARD, WALTER I—Dist. mgr., Massey Harris Co., Ltd., Toronto, Ont., Canada.

WEEKS, PRESTON H—Parts mgr., Whitmer Irwin, Inc., Hartsville, S.C.

WELCHERT, WILLIAM T—Asst. ext. agr. engr., South Dakota State College, Brookings, S.D.

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WILLIAMS, SYDNEY J. A—Student, Ontario Agricultural College, Guelph, Ont., Canada.

WRIGHT, HAROLD E—Machine dept. mgr., Norwich District Co-op., Norwich, Ont., Canada.

YALE, JULIUS R—Trainee, Macalaster Bicknell Co. of Connecticut, Inc., New Haven, Conn.

YOUMANS, DONALD W—Asst. mgr., Youmans Farms, New Scotland, N.Y.

A Correction

"Mechanical Ventilation of Stored Grain"

THE paper entitled "Mechanical Ventilation of Stored Grain" was inadvertently published in AGRICULTURAL ENGINEERING for November, 1951 (pp. 606-608), without corrections and additions recommended to the authors by representatives of the various agencies cooperating in the study reported. The following are some of the more important corrections and additions suggested:

In the first paragraph (p. 606) no mention is made of moisture transfer by diffusion and hygroscopic absorption. There is a tendency for moisture to move from grain with higher vapor pressure to that with lower vapor pressure even in the absence of air movement. While the major moisture movements that cause damage apparently depend on convection for carrying the vapor, transfer by diffusion no doubt has more or less part in the resulting wet spots.

It should also have been noted in paragraph 3 that the moldy and caked layer of corn makes fumigation difficult. For effective fumigation it is necessary to break up the caked layer before the fumigant is applied.

By the way of definition "flat-type" or "flat" storage, as used in the paper, refers to large grain buildings in which the grain depth is shallow relative to the width or length, as contrasted to the silo-type structure usually used in large commercial grain storages.

To further clarify Fig. 6 (p. 608), each of the numbered lines on the graph represents the average moisture content of 15-in layers of grain. The layers are numbered from 1 to 7 from top to bottom in the direction of air flow. Line A represents the average moisture content of all the grain in the bin.

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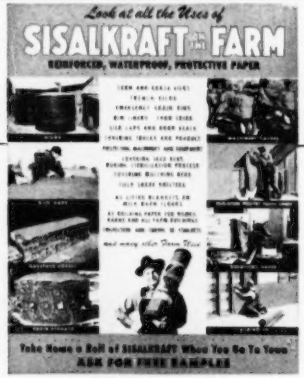
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Personnel Service Bulletin

The American Society of Agricultural Engineers conducts a Personnel Service at its headquarters office in St. Joseph, Michigan, as a clearing house (not a placement bureau) for putting agricultural engineers seeking employment or change of employment in touch with possible employers of their services, and vice versa. The service is rendered without charge, and information on how to use it will be furnished by the Society. The Society does not investigate or guarantee the representations made by parties listed. This bulletin contains the active listing of "Positions Open" and "Positions Wanted" on file at the Society's office, and information on each in the form of separate mimeographed sheets, may be had on request. "Agricultural Engineer" as used in these listings, is not intended to imply any specific level of proficiency, or registration, or license as a professional engineer.

NOTE: In this bulletin the following listings still current and previously reported are not repeated in detail; for further information see the issue of AGRICULTURAL ENGINEERING indicated:

POSITIONS OPEN: JULY—O-401-529. AUGUST—O-520-533. SEPTEMBER—O-340-549, 553-540, 555-542. OCTOBER—O-401-544, 596-545. DECEMBER—O-457-547, 451-548, 450-549, 473-550, 480-551.

POSITIONS WANTED: MAY—W-253-54, 276-56. JUNE—W-252-60. AUGUST—W-515-70, 292-71. SEPTEMBER—W-341-72, 333-73, 334-74. OCTOBER—W-388-76, 401-78. NOVEMBER—W-419-80. DECEMBER—W-459-81, 464-82, 461-83, 454-84, 467-85, 471-87, 470-88, 477-89.

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DISTRICT SALES MANAGER (2 openings) to select, train, and supervise dealer organizations in specialized farm equipment for division of a large manufacturer. Territory open in Iowa, Nebraska, Dakotas, and Minnesota. Want men with four years of college training in agricultural engineering, or in horticulture, entomology, or plant pathology, with 5 to 10 yr sales and sales supervision experience. Industrious, cooperative in following policies, with organizing ability and sales leadership. Opportunity for advancement to assistant sales manager, sales manager and higher administrative positions. Age 25 - 35. Salary $3600 and graduated bonus averaging $150 to $300 per month. O-494-552

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DESIGN, development, extension, research, or sales in soil and water field, with industry or public service, perferable in Southeast. Willing to travel. BS deg in agricultural engineering, with additional work toward MS deg, Virginia Polytechnic Institute. Experience in S C S research since February 1949. War enlisted service in Navy nearly 3 yr. Married. Age 26. No disability. Available now. Salary open. W-485-90

DESIGN, development, or research in power and machinery field with manufacturer, processor, or consultant, preferably in eastern U.S. BS deg in agricultural engineering, North Carolina State College. MS deg in agricultural engineeering to be completed by Jan. 1, 1952. Mechanized farm background. Auto mechanic and garage operator one year. Two summers at North Carolina State College on design and development of the finger wheel rake. Married. Age 24. No disability. Available now. Salary open. W-488-91

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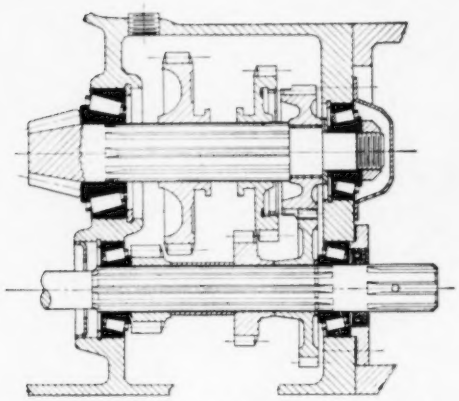
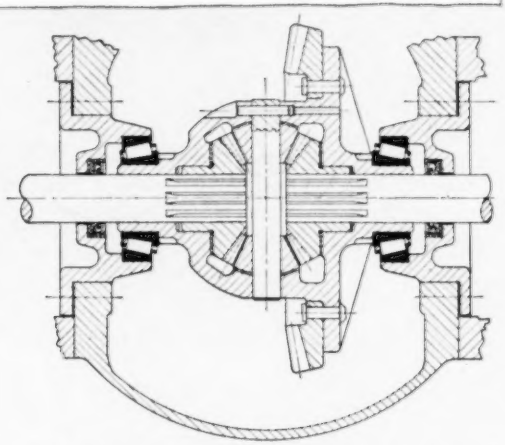
MORE AND MORE IMPLEMENTS ARE USING THEM, TOO!**





Transmission and differential of Allis-Chalmers Model B tractor—another farm machine in which the agricultural engineer has solved three of his biggest design problems by using Timken bearings. In the transmission (left) the Timken bearings are directly mounted on the input shaft and indirectly mounted on the pinion shaft. Metal shims adjust input shaft bearings. Pinion shaft bearings are adjusted with a nut. The differential bearings are shim-adjusted, directly mounted.

How Allis-Chalmers keeps shafts aligned, gears meshing smoothly in Model B tractor

WITH Timken® bearings in the transmission and differential of this Model B tractor—Allis-Chalmers engineers solved three of their biggest design problems—1) combination loads, 2) ease of operation, 3) dirt.

Timken bearings take radial and thrust loads in any combination and practically eliminate friction. Shafts are held in positive alignment with a minimum of deflection and end-play. Gears mesh smoothly and accurately, reducing wear and insuring a smooth flow of power. Because Timken bearings hold shafts and housings concentric, seals are more effective. Dirt and water stay out—lubricant stays in.

With the increasing importance of greater precision in farm implements, engineers are turning more and more to Timken bearings to solve their bearing problems. And as a result, implement users are assured of longer implement life, less chance of breakdown in the field, less-frequent lubrication and higher towing speeds.

For more information about Timken bearings write now for your free copy of "Tapered Roller Bearing Practice on Current Farm Machinery Applications". The Timken Roller Bearing Company, Canton 6, Ohio. Cable address: "TIMROSCO".

The farmer's assurance of better design →

Tapered Roller
TIMKEN BEARING
EQUIPPED

NOT JUST A BALL ○ NOT JUST A ROLLER ⊂⊃ THE TIMKEN TAPERED ROLLER ⊂⊃ BEARING TAKES RADIAL ⟋ AND THRUST → ⊃ LOADS OR ANY COMBINATION